ELECTROMECHANICAL

components & systems DESIGN

OCTOBER 1961

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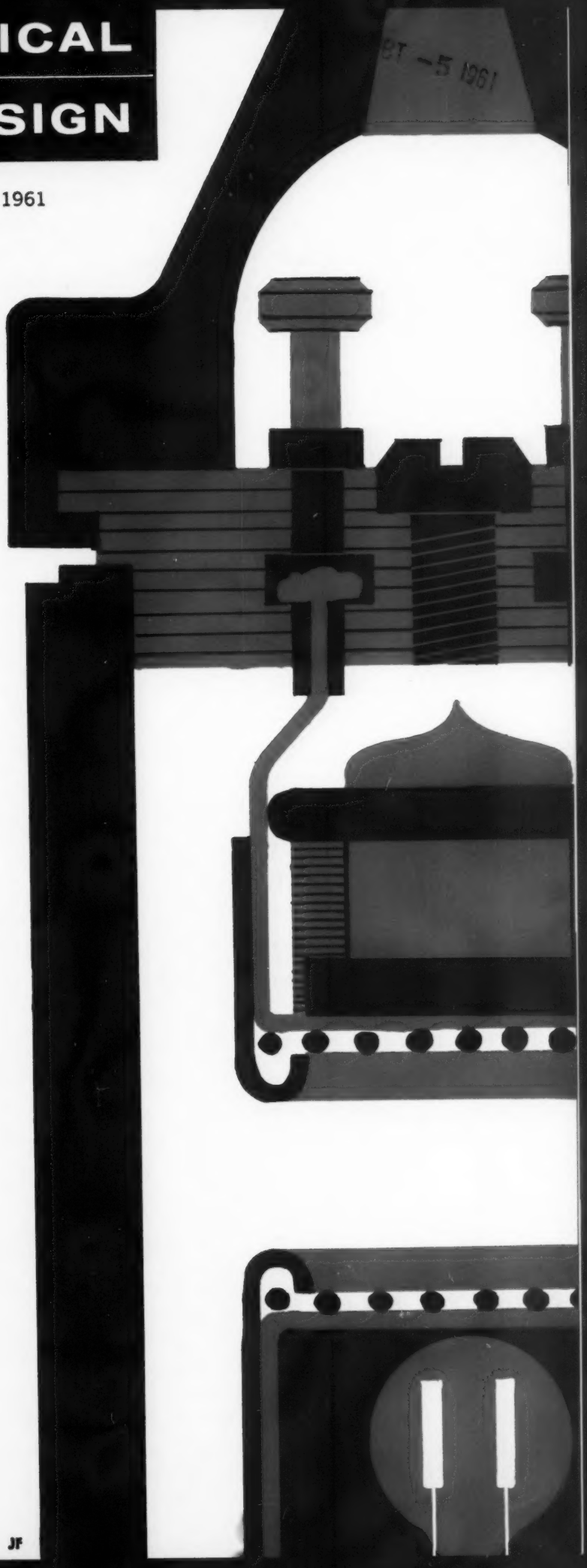
in this issue

high voltage control



JF

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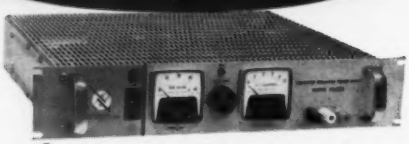

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Power Sources is a subsidiary of Technical Operations, Incorporated giving it the flexibility and efficiency of a small autonomous company, plus the advantages of scientific strength, financial backing and long range planning of a large corporation.

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HIGH VOLTAGE	PS4222M	PS4232M
Voltage Range (VDC)	35-215	115-325
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Regulation (line)	<0.1% or 0.2 v, over entire input range	
Regulation (load)	<0.1% or 0.2 v, zero to full load	

LOW VOLTAGE	PS4305	PS4330*
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*May be paralleled up to quantity of three to provide 90 amp operation.

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Regulation (load)	0.1% maximum	

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CIRCLE NO. 1 ON INQUIRY CARD

ENGINEERING NEWS-#8

SIX PUSHBUTTON SWITCHES

CHECKED	ENGR.	CONTROL SWITCH DIVISION

SUB-SUBMINIATURE

B7000 is only 11/32" diameter, 1¼" total length. Available with a bushing or flange mounting. Flange can be engraved. Anodized aluminum case, plastic plunger cap and solder lugs. Rated 1 amp at 28 VDC. The perfect pushbutton for subminiaturized instruments and control panels.

MOISTURE-PROOF, 6 CIRCUIT TYPES

W100 is available at S.P.S.T. (N.O. or N.C.), S.P.D.T., 2-circuit, and 3-terminal (N.O. or N.C.). Designed to MIL-S-6743, MS-25089. Completely moisture-proof and enclosed in anodized aluminum case with silicon rubber boot. Available with any of 8 mounting adapters (Adapter P shown) to meet any mounting or panel requirement. Rated 10 amps at 28 VDC resistive.

LOW COST, U.L. LISTED

B2000 series switches are considerably smaller than standard ½ amp momentary pushbuttons, yet cost much less and actually are U.L. rated at 8 amps, 120 VAC. Select S.P.S.T. circuit either N.O. or N.C., with solder lugs or pigtail leads. Mounts in ½" dia. hole.

WITH OR WITHOUT LIGHT

WC1500 is a very small moisture-proof switch (designed to MIL-S-6743) with a minimum life of 25,000 operations at rated load. Available with or without indicator light in pushbutton, and rated at 2 amp ind. or 4 amp res., 28 VDC. D.P.D.T. or 4-circuit. Mounts in ⅜" diameter panel hole.

MOISTURE-PROOF, ALTERNATE ACTION

J3136 is a new moisture-proof switch originally designed for military ground support and aircraft equipment. Two-circuits, rated at 5 amp ind. or 10 amps res. at 28 VDC: 5 amp (.75 P.F.) ind. or 10 amp res. at 120 VAC. Life is 25,000 operations min. at rated load. Anodized aluminum case with solder lug terminals, and 8 styles of mounting adapters available. Mounts in ⅝" dia. hole.

20 AMPS., PUSH-PUSH

J100 is a S.P.S.T. switch rated 20 amps res. at 28 VDC; 10 amps res. at 115 VAC. Ruggedly built to give compactness and durability under crictical operating conditions. Weighs only 1 oz. Total plunger travel is only ¼". Overall size: 1" diameter, 2 15/32" long.

The switches shown above are merely samples from the full line of CONTROL SWITCH pushbuttons. Perhaps one of these is a solution to a switching problem you face. If not, write for your **free** copy of CATALOG 100 for details on the wide range of switches available, including basic switches, toggles, lighted pushbuttons, indicator lights and many other types.

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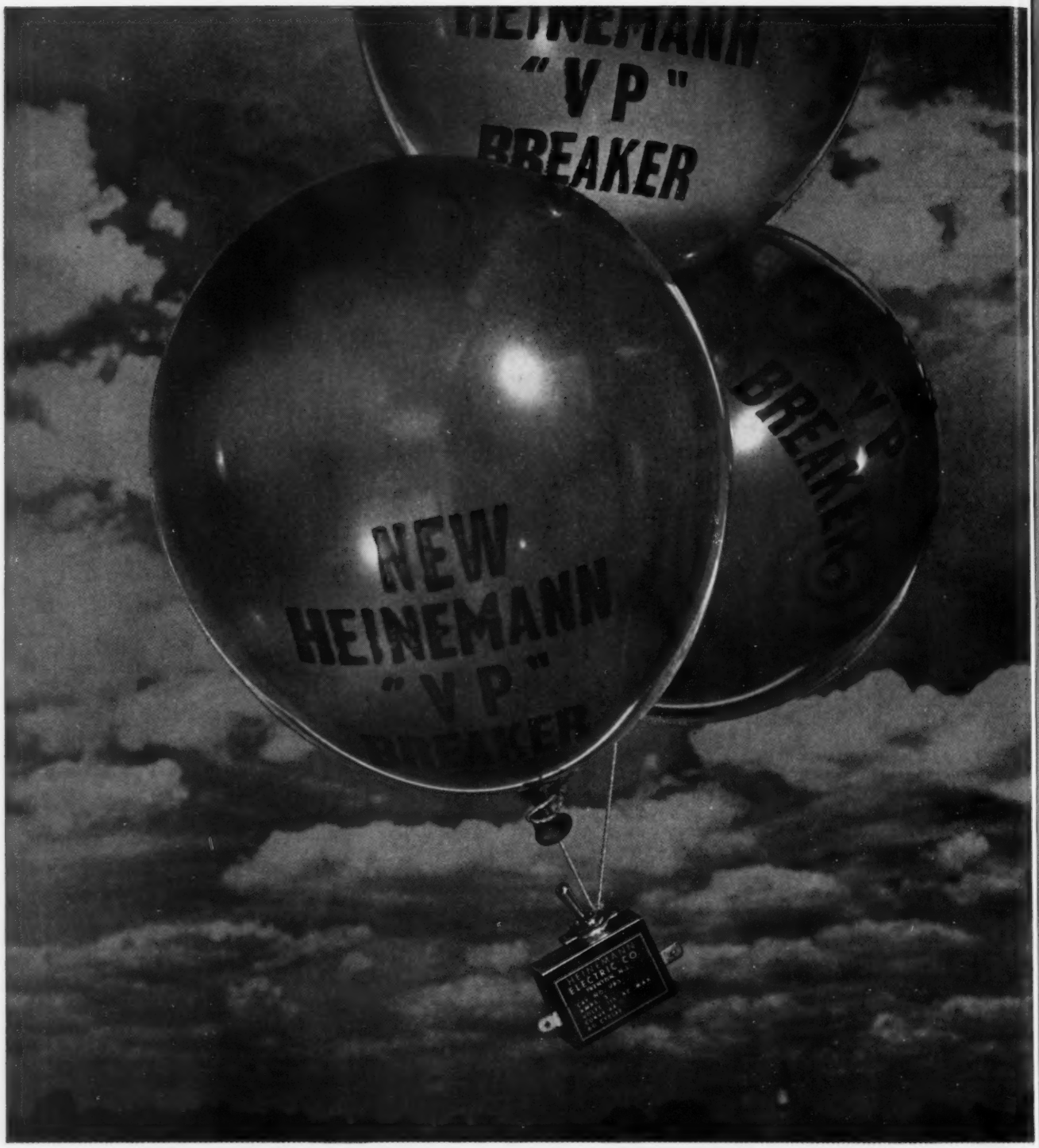

Only 1-1/2 ounces (including the switch plate)

Heinemann's new Series VP may well be the lightest circuit breaker made. For sure, it's one of the smallest and most compact you'll find around. Yet, remarkably, it's capable of handling all the functions of much larger Heinemann breakers.

It is temperature-stable. Current rating and calibrated trip-points are completely unaffected by ambient temperature. No derating . . . ever.

It is available with a choice of time relays. You can have either a "fast" or "slow" delay. Or instantaneous response.

It can be furnished with any of Heinemann's special-function internal circuits. With a little ingenuity and a special circuit, you can make the breaker do such out-of-the-ordinary chores as remote switching, circuit "slaving," alarm signaling.

The matchbox-size Series VP is available in any integral or fractional rating you might need, from 0.050 to 15 amps (at 110V, 60 or 400 cycles AC, or 50V DC).

Bulletin VP will give you detailed specifications and dimensions. A copy is yours for the asking.

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CIRCLE NO. 3 ON INQUIRY CARD

ELECTROMECHANICAL
components & systems DESIGN

The Sourcebook of Design Ideas in Applied Electromechanics

OCTOBER 1961 • VOL. 5 NO. 10

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BPA Circulation for October over 29,000

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Brookline 46, Massachusetts

NEW MINIATURIZED LONG-LIFE COMMUTATION SWITCH

ACTUAL SIZE
Plate dia. only 1 3/4"

. . . but 1¾" plate diameter and 50% space savings* in a 180-channel switch are only the start of the story. This new electromechanical switch also gives the other advantages that have made MYCALEX® units the industry standard. Noise level of less than 1 millivolt when switching 5 volts into a 150-ohm load. Up-to-a 1000 megohm resistance between rectangular contacts. Speeds as high as 1800 RPM. Metal-to-metal wiping action that prevents graphite build-up. Super-hard, gold-plated contacts. SUPRAMICA® 555 ceramoplastic plate that withstands operating temperatures to 650° F., has *total* dimensional stability, locks contacts in place. *Plus* nylon-brush mountings of new design that eliminate bounce and deliver sharp, clean signal edges.

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SMALL
SIMPLE
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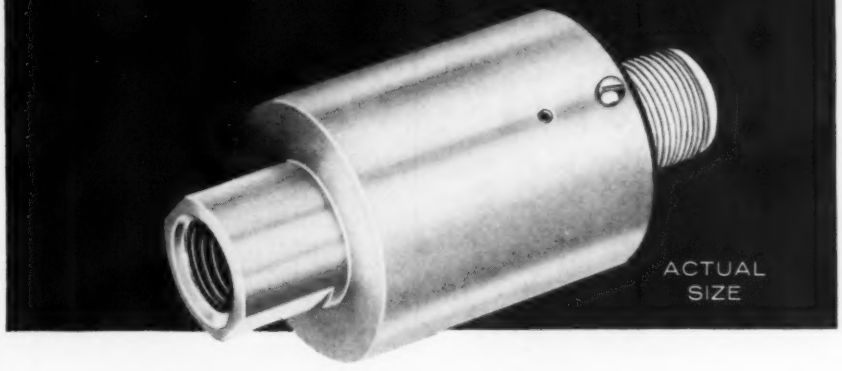

New low-cost altitude pressure switch with accuracy over wide temperature range

Here is another new pressure switch from Consolidated Controls with an important combination of benefits: small, simple, light, low-cost.

The Ni-Span-C sensing element gives you accuracy over a wide temperature range, operating in conjunction with a sub-miniature snap-action switch. What's more, it is field adjustable because special internal stops permit adjustment over the entire altitude range by simply turning the snap-action switch assembly. Only a vacuum pump and gauge are necessary for calibration.

The unit is completely "O"-Ring sealed and housed, within one-piece anodized aluminum case. Electrical connector is independent of adjustment mechanism.

Available as absolute, gauge or vacuum unit, the Type 214C50 pressure switch is also offered with a variety of pressure and electrical connections. For full details, write or telephone Mr. Charles Colt, Bethel, Conn., Pioneer 3-6721, DDD Code 203.

Performance characteristics of Type 214C50 Altitude Switch

Adjustment range — sea level to 70,000 feet
Accuracy — 2% from —65 to 250°F.
Vibration — Mil-E-005272C procedure XII
Life — 50,000 cycles minimum
Contract arrangement — SPST, SPDT, normally open, normally closed
Weight — 3¾ ounces, without bracket

CONSOLIDATED CONTROLS CORPORATION

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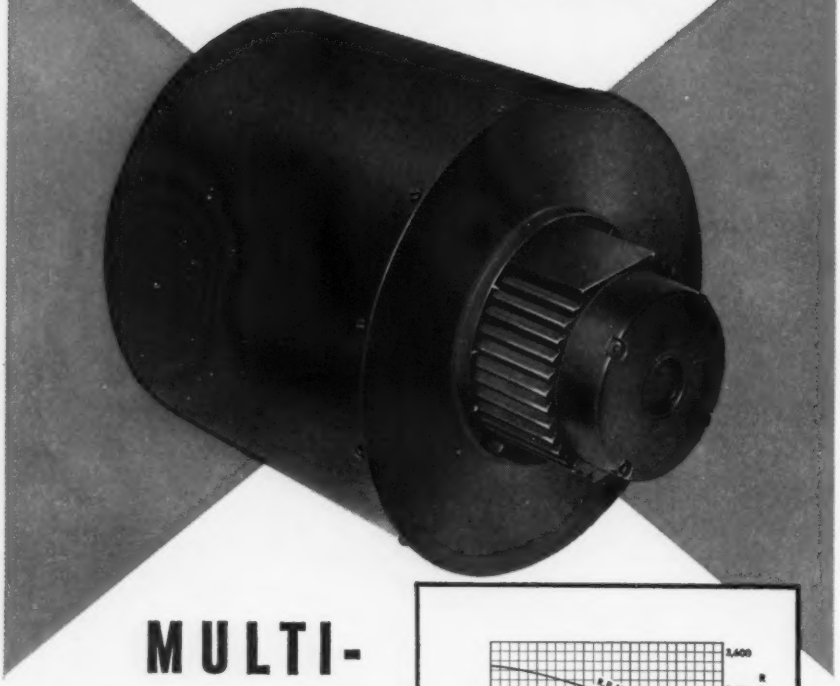
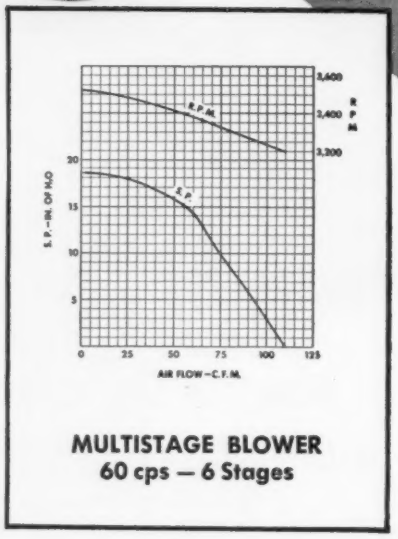
the pressure's on for '61



MULTI-STAGE BLOWER

60 cps or 400 cps
1ϕ or 3ϕ
To 440 Volts
10" O.D. by lengths up to 14"
Ambient Range: —55° + 85° C
Commercial or Military



MULTISTAGE BLOWER
60 cps — 6 Stages

When engineering specifications require continuous duty and quiet long life, Air Marine offers multistage blowers for low volume, higher pressure applications to 1 psi with air delivery to 100 CFM. Featured is long life with low noise. Where high pressure is required or on such vacuum applications as tape retention, the Air-Marine multistage blowers are the efficient answer.

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CIRCLE NO. 6 ON INQUIRY CARD

LETTERS

GENTLEMEN'S AGREEMENT

It was a pleasant surprise to read your editorial in the August issue of Electromechanical Design. All too frequently do editors of magazines miss the opportunity to present new and intelligent appraisals of current problems in the engineering profession. Your present editorial is certainly one of the finest I have ever seen in many years.

D. Wolkov
Airborne Instruments Laboratory
Division of Cutler-Hammer, Inc.

To date only two people agreed with Wescon's "Gentlemen's Agreement" — no overt hiring of engineering personnel at the show — and they were officially connected with Wescon. Our editorial disagreed with this policy and Mr. Wolkov's letter is representative of those engineers who called or wrote us with regard to our views.
— H. G. B.

KUDO'S

I would like to tell you of my high regards for your fine magazine. As the Director of Engineering I am always referring articles of interest to my engineers. I find your articles very helpful and interesting.

Sid Davidson
KOA TV-Radio
Denver, Colorado

. . . I would like to have each of our Systems Division design and development engineers receive their own individual copies of your fine publication as this publication, more than any other one, is active in our fields of endeavor. Therefore, I would appreciate it very much if you would arrange for complimentary subscriptions for the people whose names are on the enclosed sheet.

Edward J. Gately, Jr.
Manager, Systems Division
Clifton Precision Prods., Inc.
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(Continued on page 8)

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X-15 launched from B-52 "mother" plane. U. S. Air Force photo.

Mile-a-second X-15 carries Bristol pressure sensor

Research airplane X-15, a joint Air Force, Navy and NASA project, has already carried man faster than he has ever flown before—more than 0.7 of a mile a second—and is expected to exceed a mile a second.

A vital part of the plane's intricate fuel control valve assembly—made by Whittaker Controls Division of Telecomputing Corporation, Los Angeles—is a Bristol capsular pressure element.

Though differing in details, the X-15's capsular element features the same precision construction, carefully selected and controlled material—the same linearity, low hysteresis and high reliability that have gone into Bristol pressure measuring instruments for more than seventy years.

They're the same qualities that result in more Bristol recording gauges being used than all other makes combined.

Bristol capsular elements.

Today, because of expanded facilities, Bristol offers the aircraft and missile industry *from stock* a selection of popular and representative high-precision Ni-Span C capsular elements (Bulletin AV2001)—as well as pressure switches for gauge, absolute, and differential pressures (Bulletin AV2016) featuring the same elements. Write for complete information on these units—and, of course, we'll be glad to discuss your special requirements.

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W/L on target!

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As a supplement to the unexcelled VITROHM resistors, Ward Leonard now offers to designers of commercial, military and industrial electronic equipment a line of molded metal film precision resistors, designed and tested to exceed the requirements of MIL-R-10509D, characteristics B, C and E. You can stake your reputation on Ward Leonard resistors.

Available in ⅛, ¼ and ½ watt sizes, W/L METOHM precision resistors feature the highest degree of built-in reliability and operating stability. Temperature coefficients, over the range −55°C to +175°C, may be as low as ±25 parts per million. Standard tolerance ±1%. Tolerances down to ±0.1% on special order.

METOHM TYPE	MIL EQUIVALENT	RATED WATTS	OHMIC VALUES		MAX. VOLTAGE RATING
			MIN.	MAX.	
WL 60	RN 60	⅛	30	500K	250 V.
WL 65	RN 65	¼	50	1 meg.	300 V.
WL 70	RN 70	½	50	1.5 meg.	350 V.

Write for complete specifications and a list of distributors. Ward Leonard Electric Co., 15 South Street, Mount Vernon, New York. 0.10

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RESISTORS • RHEOSTATS • RELAYS • CONTROLS • DIMMERS

CIRCLE NO. 8 ON INQUIRY CARD

LETTERS

(Continued from page 6)

fied engineers. Just send us their names on your company letterhead and we'll send each of them qualification cards similar to that facing the inside back cover of the magazine. No one can be added to our circulation list until a card of this type has been filled out and found qualified by our circulation department. — Ed.

COMPONENTS DIGEST COMMENT

I have received the June issue of Electromechanical Design, and after a month delay in reading it due to an extended business trip, have been pleased to find that your publication is one of the better technical magazines available. I would like to be on your circulation list and, further, since your components digest on semiconductor devices falls directly in my field of interest (effects of nuclear radiation on semiconductor devices and circuits), I would be very interested in obtaining a copy of Part I and Part II of this article if possible. These articles should be very popular as reprints, if you should make them available as such.

L. J. Zipprich
Organization 5433
Sandia Corporation
Albuquerque, N.M.

. . . Your article, "Semiconductor Devices, Part III," has been received with much enthusiasm both by myself and by my co-workers. The conciseness and completeness of the article makes it a valuable aid to our work here. We would very much appreciate your sending us a copy of Part I and a copy of Part II of that article.

J. F. Escatell
Autonetics
Division of North American
Aviation, Inc.
Downey, Calif.

We're happy to handle requests such as these on any articles and material on a first-come first-served basis. A limited amount of Parts I and II are still available until they run out. —Ed.

Is it a relay or coaxial switch?

Some people call this electro-magnetically actuated device a relay. We call it a coaxial switch. Do you know what the difference is?

First, the conventional relay, even when shielded and coaxially terminated isn't suited for use in circuits above 400 mc. In fact, even at this relatively low frequency, such a relay may have a VSWR of 1.5. The DK Coaxial Switch with improved impedance match will show a VSWR of only 1.1 at the same frequency.

Standard DK Coaxial Switches are designed for frequencies up to 5,000 mc. Models under development will soon extend this to the 10,000 mc range.

Improved VSWR is only one difference. DK Coaxial Switches offer *lower crosstalk, reduced insertion losses,* and great *environmental reliability.*

RF Products can supply over 1300 individual switch designs. But, since 132 of these meet 90 per cent of known applications, we have prepared a simplified catalog which makes it easy for you to find the switch you need. Write for Catalog DK61.

If you don't find the switch you want in this catalog, your local RF Products representative can supply you with information on hundreds of existing alternatives, or help you to design a new switch to solve your specific problem.

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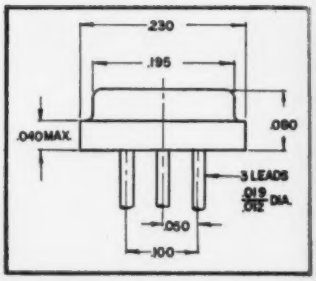
ipc AMPHENOL

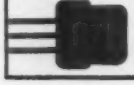
CIRCLE NO. 9 ON INQUIRY CARD

NPN SMALL SIGNAL SILICON TRANSISTORS TO-46



the Smaller, PRACTICAL Package— from NSC, the Small Signal Source!

The NS475 series — newest addition to NSC's growing line of quality Small Signal transistors — in the smaller TO-46 "pancake package." Utilizing a glass-to-metal hermetic seal, the TO-46 is one-third the height of the TO-18 — simplifying circuit design — yet has the same diameter, for direct replacement of TO-18 package.

PARAMETER	NS475	NS476	NS477	NS478	NS479	NS480
min. BV_{CBO} min. BV_{CEO}	30v	30v	30v	60v	60v	60v
min. BV_{EBO}	6v	6v	6v	8v	8v	8v
h_{fe}*	20-50	40-100	80-300	20-50	40-100	80-300
max. I_{CBO}†	.2μA	.2μA	.2μA	.2μA	.2μA	.2μA
max. V_{CE}††	1v	1v	1v	1v	1v	1v
max. C_{ob}	8pf	8pf	8pf	8pf	8pf	8pf
min. F_T	80mc	80mc	80mc	80mc	80mc	80mc
PHYS. PACKAGE	can be used to replace	can be used to replace	can be used to replace	can be used to replace	can be used to replace	can be used to replace
TO-18	2N761	2N762		2N734 2N754 2N756 2N756A 2N757 2N757A	2N735 2N759 2N759A	2N736 2N760 2N760A
TO-5	2N332 2N332A 2N337 2N473 2N474 2N475	2N335 2N335A 2N338 2N470 2N471 2N472 2N478 2N479 2N480	2N336 2N336A 2N541 2N542	2N1564	2N335 2N335A 2N1565	2N336 2N336A 2N543 2N1566
TO-22 	2N1149 2N1150 2N117	2N1152 2N118	2N1153 2N119	2N1147 2N1150 2N117	2N1152 2N118	2N1153 2N119

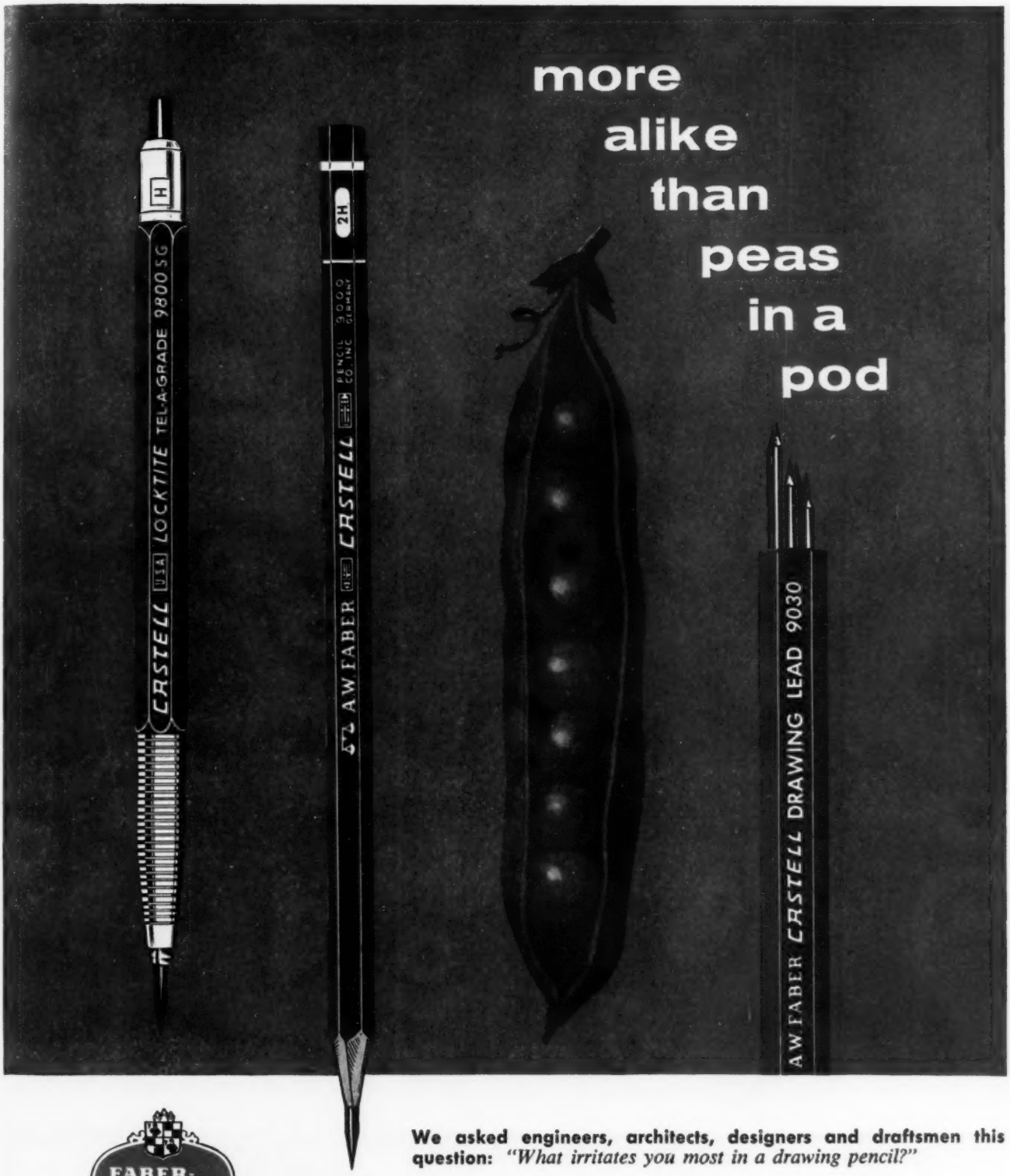
*V_{CE} = 5v, I_E = 10mA †V_{CB} = 50% BV_{CBO} ††I_C = 10mA, I_B = 1mA

For complete technical data on all Small Signal transistors, call, write or wire:

National Semiconductor CORPORATION

Danbury, Conn. • Pioneer 3-7624 • TWX DANB 452-U

CIRCLE NO. 10 ON INQUIRY CARD



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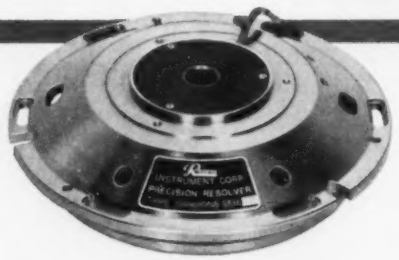
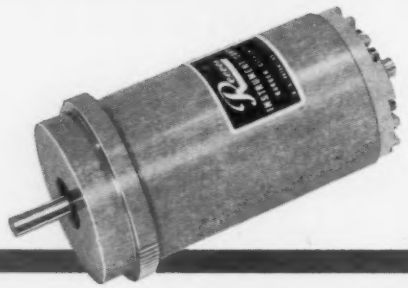


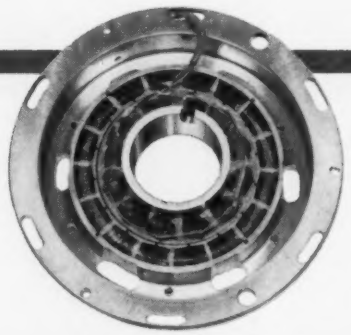
10-SECOND ACCURACY PANCAKE RESOLVER

Integral bearings permit direct mounting to gimbal structures of stable platforms. Beryllium housings provide highly stable operation in environments with extreme temperature variations.



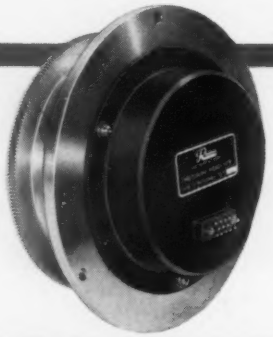
20-SECOND ACCURACY SIZE 23 RESOLVERS

Double-ended design simplifies their incorporation into data transmission systems.



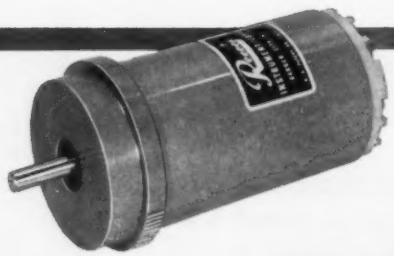
HIGH IMPEDANCE PANCAKE RESOLVERS

Tuned impedance of 80,000 ohms makes these units ideally suited for use as control receivers. Rotor and stator assemblies may be independently attached to their mounting members. Standard units have an accuracy of **3 minutes of arc.** One-minute accuracy can be supplied on special order.



0.005% FUNCTIONAL ACCURACY PANCAKE RESOLVER

100% compensated Resolver with integral Class III precision rotor gear. The ideal unit for high accuracy computer chains.



0.01% FUNCTIONAL ACCURACY SIZE 23 RESOLVER

100% compensated winding. Extreme accuracy in a standard resolver case size.

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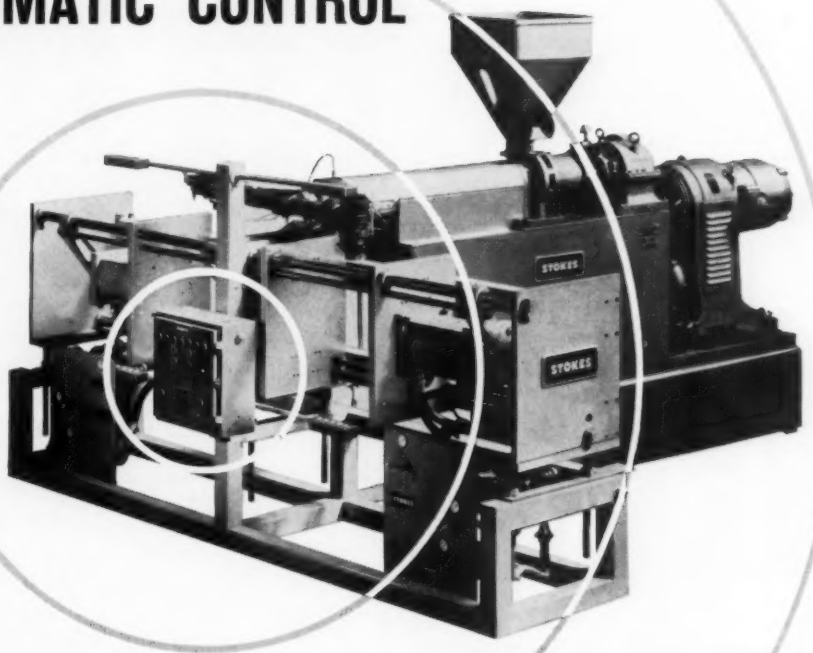
AN INDUSTRIAL TIMER FOR AUTOMATIC CONTROL



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The production of hollow plastic articles (containers, dispensers, etc.) has been boosted immeasurably with the development of "High Capacity Stokes Dual - Manifold Blow Molder".

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Wherever precise timing controls are required in industrial processes, or in equipment, Industrial Timer Corporation has the wide range of instruments, the wide experience in applying them, that assure the perfect answer to your problem.

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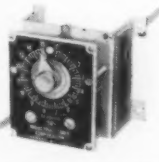

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INLAND

Standard DC Torquers available in the widest range of sizes and capacities

Silent, gearless, Inland DC pancake torque motors have high torque-to-inertia ratios and excellent linearity throughout the torque range. They provide an exceptional degree of accuracy for direct-drive servo positioning, while eliminating problems of backlash, windup, and compliance.

Inland's complete line of DC torquers serves in such varied applications as: missile and aircraft stable platforms, radar tracking antenna, space vehicle reaction wheel drive, rate table drives, rotary solenoids for missile arming systems, and special machine tool applications—just to name a few.

For systems duty with Inland torque motors, a line of rotary and solid state amplifiers is also available. All Inland products are backed by extensive experience . . . thorough quality control, reliability, and field testing . . . successful performance in practically every major missile and space vehicle program. For details, complete specifications, and illustrated brochure, write Department 410.

Standard Model Specification Range
from smallest to largest torque motors*

FRAME SIZE	1.3 INCHES	36.0 INCHES
Peak torque, lb.-ft.	0.1	3000
Volts at peak torque, stalled at 25°C	48	246
Amps at peak torque	1.21	30
Sensitivity, lb.-ft./amp	.09	100
Temperature rise per watt, ultimate, °C	13.4	0.04
Total friction, lb.-ft.	0.003	18
Ripple torque, pound-feet		
At low torque levels	0	0
At peak torque	0.1	trace
Weight, lbs.	0.313	1200

*Numerous sizes available in between. Non-Standard sizes designed to meet specific requirements in these ranges and larger.

INLANDMOTOR
CORPORATION OF VIRGINIA
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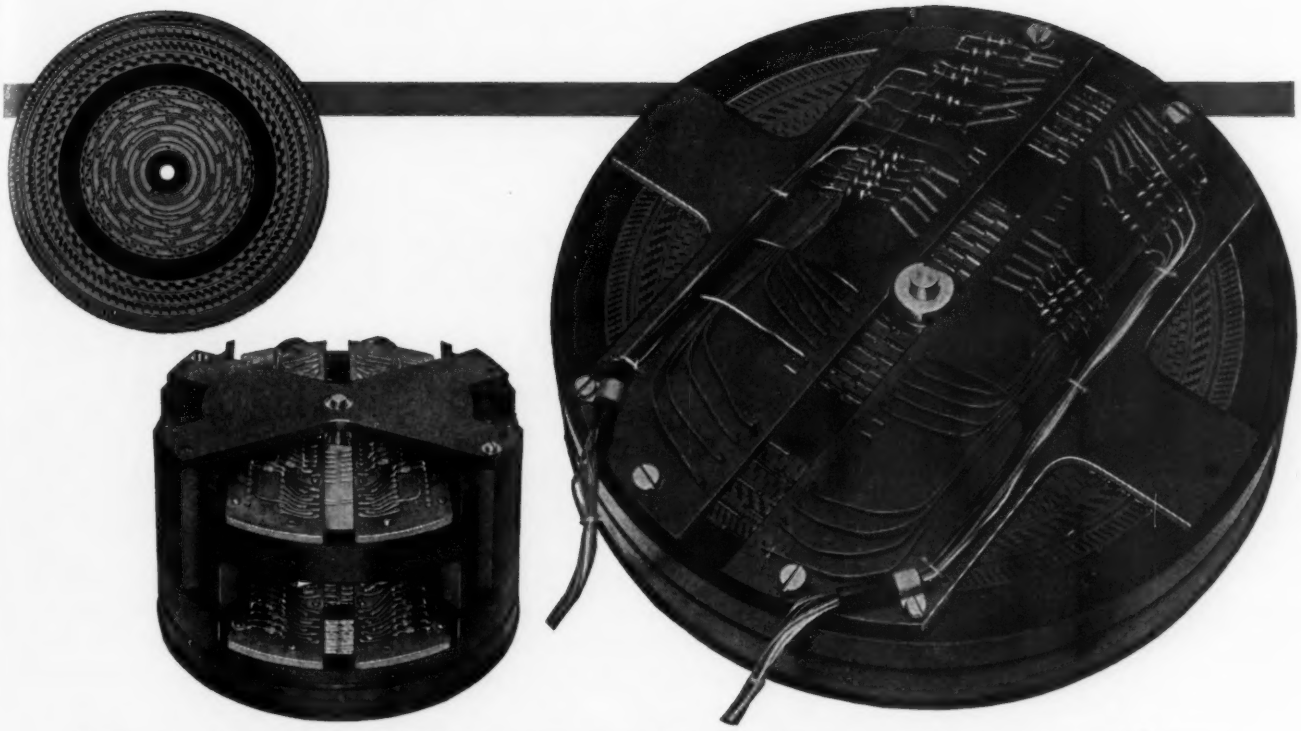

Now Norden binary-coded decimal converters for commercial application

- **1000 count per turn**
- **self-contained logic**
- **self-selecting brushes**
- **continuous reading at high speeds**
- **several models in 4 2 2 1 code***

Norden offers a wide variety of binary-coded decimal shaft encoders for commercial applications. These encoders meet or surpass military specifications, and have patented, self-selecting V-brush logic.

Code disc patterns produce a totally unambiguous 8-4-2-1* binary decimal readout ranging from 2 to 6 decades. The units can be used for feeding high speed computers and servo systems . . . data logging, machine tool automation, test stands, flight check-out. Self-selecting V-scan increases reliability and life while saving space and reducing complexity and cost. Load carrying brushes never commutate. These are the only encoders that have provision for automatic self-checking gating devices for virtually 100% error monitoring.

*Several models are available in *4-2-2-1 CODE* which provides a nine's complement and makes available in a single encoder an increasing numerical count for both directions of shaft rotation.

MODEL NO.	TOTAL COUNT	REVOLUTIONS FOR FULL COUNT	ACCURACY (1 part in)
ADC-ST2-BCD	10^2	1	100
ADC-3-BCD	10^3	10	1,000
ADC-4-BCD	10^4	100	10,000
ADC-5-BCD	10^5	1,000	100,000
ADC-6-BCD	10^6	10,000	1,000,000
ADC-ST3-BCD	10^3	1	1,000
ADC-5-BCD-1000	10^5	100	100,000
ADC-3-36BCD	360	3.6	360
ADC-4-36BCD	3600	36	3,600
ADC-5-36BCD	36,000	360	36,000
ADC-6-36BCD	360,000	3,600	360,000
ADC-ST3-36BCD	360	1	360
BRL-5	360,000	1	360,000
ADC-ST2-BBCD*	10^2	1	100
ADC-3-BBCD*	10^3	10	1,000
ADC-4-BBCD*	10^4	100	10,000
ADC-5-BBCD*	10^5	1,000	100,000
ADC-6-BBCD*	10^6	10,000	1,000,000
ADC-3-36BBCD*	360	3.6	360
ADC-4-36BBCD*	3,600	36	3,600
ADC-5-36BBCD*	36,000	360	36,000
ADC-6-36BBCD*	360,000	3,600	360,000

Write Norden or call TEmple 8-4471 for complete specifications

NORDEN division of UNITED AIRCRAFT CORPORATION

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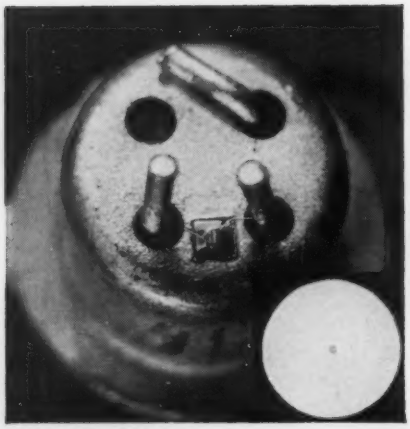
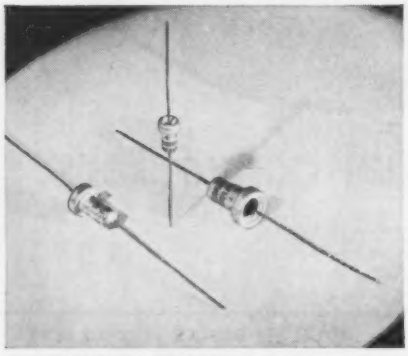
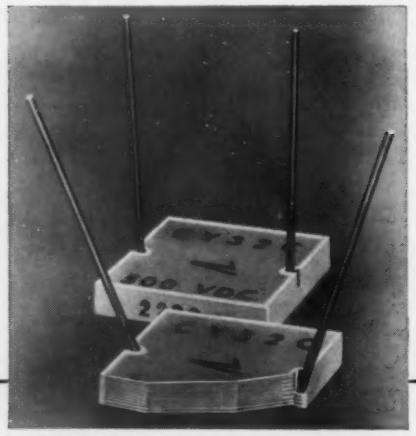
CIRCLE NO. 15 ON INQUIRY CARD



TRANSISTORS—Shown here in magnification is a Mesa transistor with fine gold wire. Handy & Harman manufactures this whisker wire to exact tolerances and highest purity standards. The cap is gold plated from Handy & Harman fine gold anodes. Photo courtesy of Western Electric.



CAPACITOR CANS—These tantalum electrolytic capacitors are completely leaktight and highly resistant to corrosion. The containers that are also used to seal the liquid and internals are drawn from Handy & Harman fine silver sheet. Photo courtesy of Fansteel Metallurgical Corporation, North Chicago, Ill.



CAPACITORS—Electrodes in these solid-state porcelain capacitors are formed from silver paste derived from Handy & Harman silver flake. Other types of capacitors for high-temperature applications have lead wires of Handy & Harman Consil 998, a nickel-bearing alloy. Photo courtesy of Vitramon, Incorporated, Bridgeport, Conn.

TRANSISTORS, CAPACITORS AND COME WHAT MAY

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CIRCLE NO. 16 ON INQUIRY CARD

CIRCLE NO. 17 ON INQUIRY CARD →

Compact 4-way

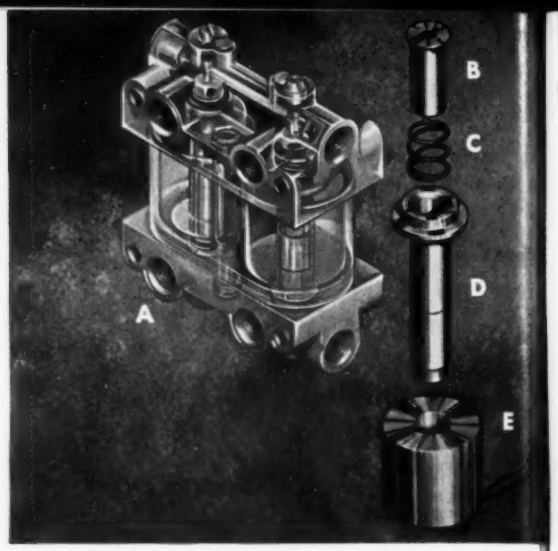
SKINNER

Solenoid Valves

assure precise cylinder control

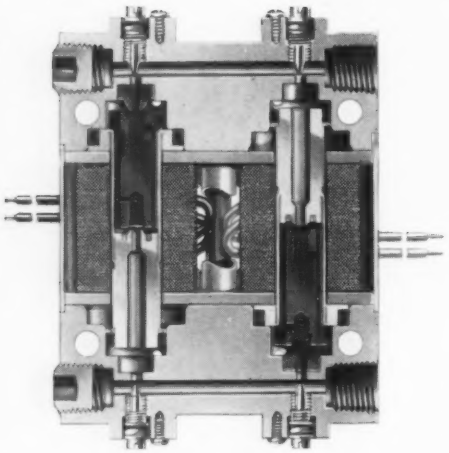
Here's how accurate, dependable operation is built into SKINNER 4-way solenoid valves

- **Precise flow control**—by adjustable metering
- **Compact, direct acting**—two 3-way valves in one housing
- **Durable and corrosion resistant**—stainless steel internal parts
- **Leakproof, bubbletight sealing**—soft, synthetic inserts
- **Positive operation mounted in any position**—spring-loaded plungers
- **Underwriters approved**—wide selection of coils, voltages and frequencies
- **Wired from front or rear**—housing easily reversed
- **Adaptable to many uses**—optional porting arrangements



A. Transparent view of 4-way solenoid valve B. Plunger
C. Plunger return spring D. Sleeve E. Coil

SKINNER four-way solenoid valves available in three basic types



The Skinner V9 solenoid valve is two 3-way valves in one compact housing. Both valves may be independently controlled and metered to provide accurate, dependable control of single- or double-acting cylinders, or larger pilot-operated valves.

V9 types are available without adjustable flow and with metering at both exhaust ports, both inlet ports or full metering of all ports.

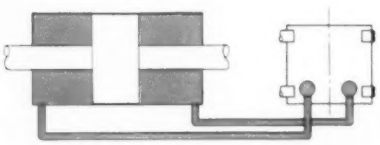
• • •

For complete information, contact a Skinner Distributor listed in the Yellow Pages or write us at the address below.

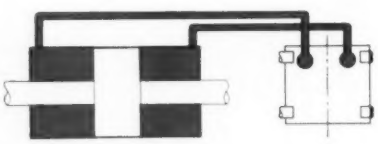
V9 SERIES SPECIFICATIONS

Media—air, hydraulic oils, inert gases
Orifice Diameter—$\frac{3}{64}$", $\frac{1}{16}$", $\frac{3}{32}$", $\frac{1}{8}$"
Pipe Size—$\frac{1}{4}$" NPTF
Maximum Operating Pressure Differential—0 to 150 PSI (up to 225 PSI also available)
Temperature Range—minus 40°F. to plus 180°F.
C_V Factor—$\frac{3}{64}$" .052, $\frac{1}{16}$" .095, $\frac{3}{32}$" .156, $\frac{1}{8}$" .214
Mounting—$\frac{1}{4}$" through-bolt holes.

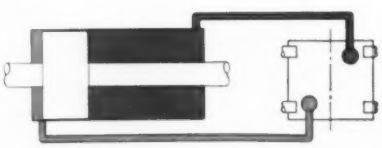
Normally closed—normally closed V933 valves with a neutral position. Generally applied on double-acting cylinders where the piston is in a neutral position without pressure when both coils are de-energized. This permits manual shifting of the piston without operating the valve.



Normally open—normally open V955 valves with a neutral position. Generally applied on double-acting cylinders where both sides of the piston are to be open to pressure when both coils are de-energized. Under certain conditions, the first operating stroke of double-acting cylinders will be smoother with this valve in use.



Normally closed—normally open V935 valves with no neutral position. Generally applied on double-acting cylinders where the piston is to be in retracted or extended position with pressure when both coils are de-energized. Wiring is simple—both coils are operated simultaneously and can be controlled by one single-pole, single-throw switch.



When you specify solenoid valves, specify Skinner. Skinner solenoid valves are distributed nationally.

SKINNER ELECTRIC VALVES ®
THE CREST OF QUALITY

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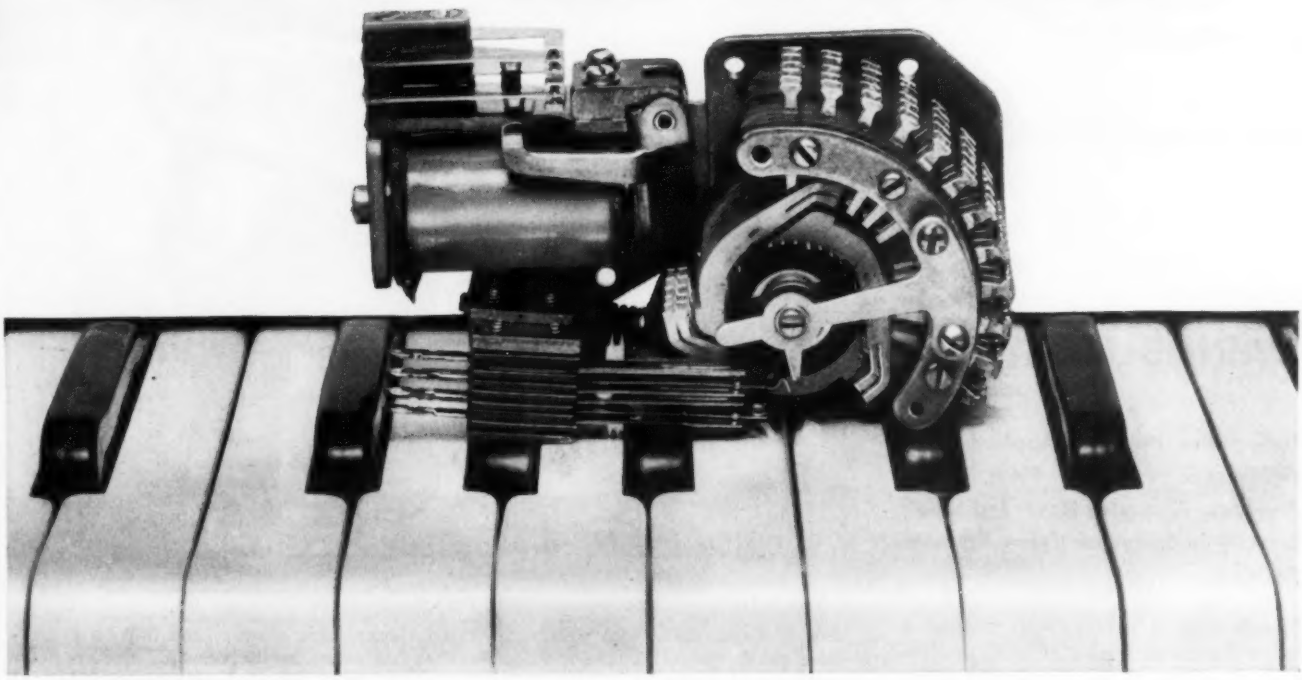


To the Engineer

looking for a small-scale switch to do a large-scale job

If you have to perform complex switching maneuvers, fast, and in small space, you'll go for AE's Type 44 Rotary Stepping Switch.

This mere handful of rugged switching accommodates up to six bank levels, with 10 points plus home—will do the work normally assigned to whole banks of relays.

The miniature Type 44, and its big brother, Type 45, are the only stepping switches with a positive-action, free-floating pawl. This unique design eliminates armature-stop and pawl-stop readjustment – prevents pawl wear-and-tear, breakage, and binding. The pawl locking teeth position the rotor automatically, making overthrow impossible.

Incidentally, AE engineers are artists at composing simple circuits to do complex things – and AE can supply assembled and prewired control packages to your specs. Either way, we can help you cut costs.

For answers to *your* automatic control problems, write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. Also ask for Circular 1698-H on Rotary Stepping Switches.

AUTOMATIC ELECTRIC

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

← CIRCLE NO. 17 ON INQUIRY CARD

CIRCLE NO. 18 ON INQUIRY CARD

VARIABLE VENTURI

Toric Valve Principle Applied To A Differential Pressure Flow Meter Provides Accurate Flow Indication Directly In Terms of Valve Actuator Position.

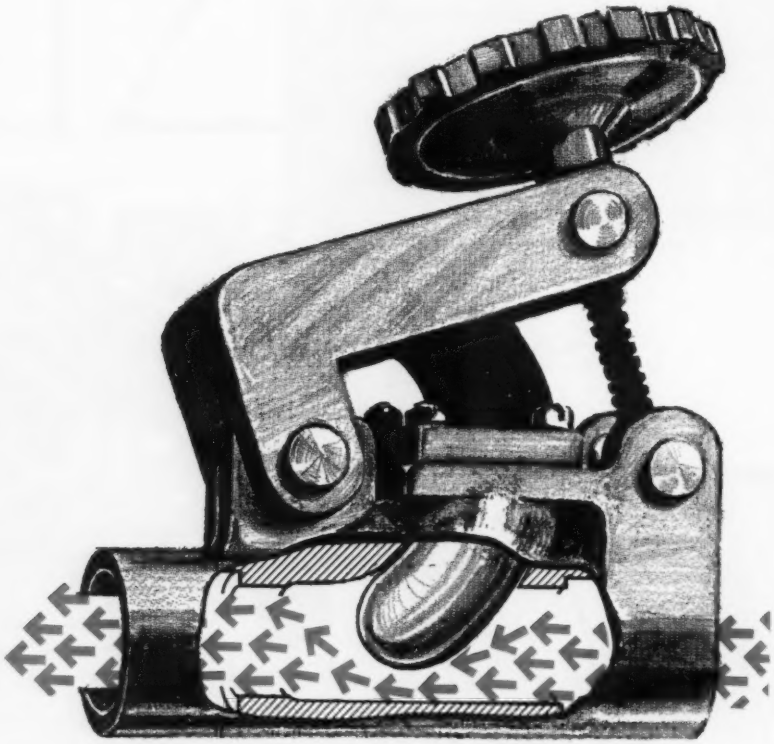


Fig 1 Toric Valve with precise throttling, logarithmic closure, and 500 to 1 flow range embodies a new principle that has many applications in electromechanical design. The valve body is a pipe with a side-passage opening for insertion of a toric plug. The passage is shaped to fit the plug so that as the plug is rotated into the body it follows the curvature of the passage, progressively closing off the flow passage. The front end of the plug is rounded smoothly so that it fits snugly in the valve seat when the valve is fully closed. Tolerances of this valve are not critical because leakage between the feed-through passage and the plug is easily prevented by packing techniques (not shown) similar to those used in conventional valves. Obvious advantages not combined in conventional valves are smooth flow, no-trapping, easy cleaning and simplicity.

Faced with a problem of finding a valve for on-off flow control of hydrogen peroxide, Roku Yasui, President of Toric Development Co., of Cambridge, Mass., was forced to design a new kind of valve based on the principle of a toric plug. Concentrated hydrogen peroxide is dangerous to handle, because it tends to be explosive when left to stand in the presence of ordinary metals used in valve manufacture. The problem was to find a valve that would not trap the liquid. Yasui reasoned that the ideal means of closing and opening a pipe line periodically without the danger of trapping would be to use a simple tight fitting plug that would completely shut off the flow when it was inserted in the pipe and would leave the flow unobstructed when the plug was removed. But how could he insert and remove a plug from the middle of a pipe line in a closed system? The answer was the Toric Valve illustrated and described in Fig 1.

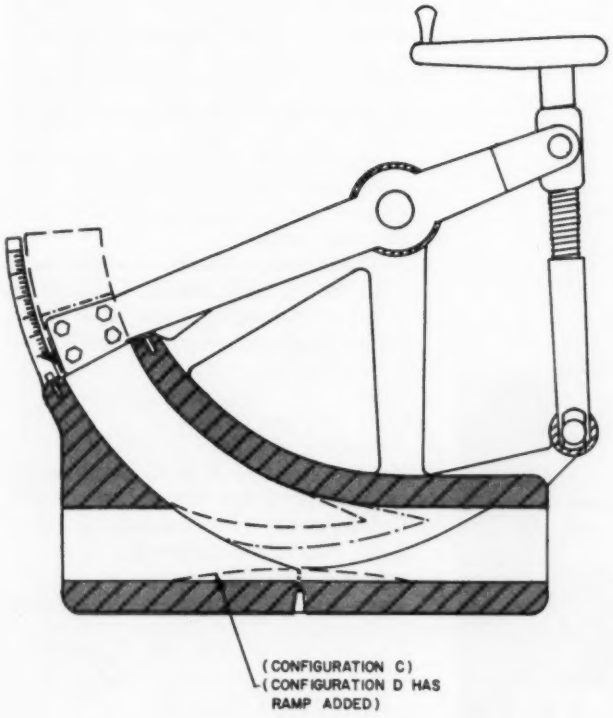
As often results when a new approach and new principles are applied in design, the Toric Valve provided many unanticipated performance benefits not combined in conventional valves. The most significant advantages are: no-trapping, tight shut off, linear semi-logarithmic flow characteristics permitting fine and repeatable flow control, wide flow range, no pressure loss when fully open, easily cleaned in place, low wear, simplicity and ruggedness.

Non-trapping, easily cleaned and flushed in place and tight shut-off characteristics of the device make it ideally suited as a sanitary valve for the food industry, and as a safe valve for handling explosive reactants (like rocket fuels) in the missile and chemical industries. The toric plug can be easily retracted for inspection purposes or for cleaning the valve without removing the valve from the line.

Regulation of the valve is precise down to 1/600 of maximum flow with repeatability. In throttling, pressure drop of the valve varies from ½ velocity head wide open to over 7000 velocity heads with good regulation.

VARIABLE VENTURI

Experience in design and development of the Toric Valve indicated many other applications of the toric principle to design of devices with unique performance characteristics: Mixing valve, flow limiter, flow and ratio controller, servo valve, vacuum valve, metering valve, cryogenic valve, control valve. The applications are limited only by the imagination of the designer. Of particular interest to electromechanical engineers is a variable venturi valve, illustrated and described in Fig 2, that allows accurate



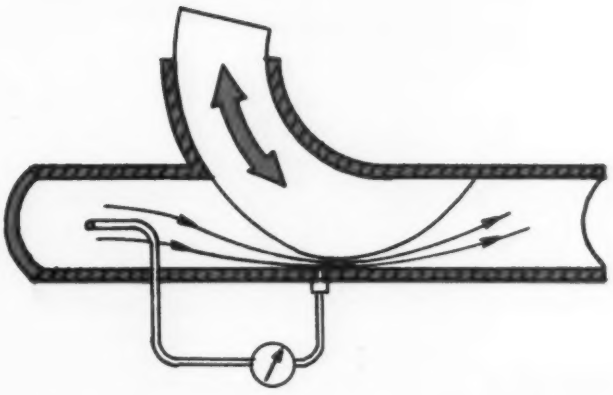


Fig 2a (left) Variable venturi valve, based on a modification of the Toric valve shown in Fig 1, provides a means for measuring or controlling fluid flow directly in terms of valve actuator position, rather than indirectly in terms of the square root of differential pressure as in the case of fixed orifices, nozzles or venturis.

Fig 2b (top right) Illustration of variable venturi valve with differential pressure meter. Varying the venturi orifice so that the differential pressure is held constant makes flow rate proportional to orifice area which in the variable venturi valve is proportional to valve position.

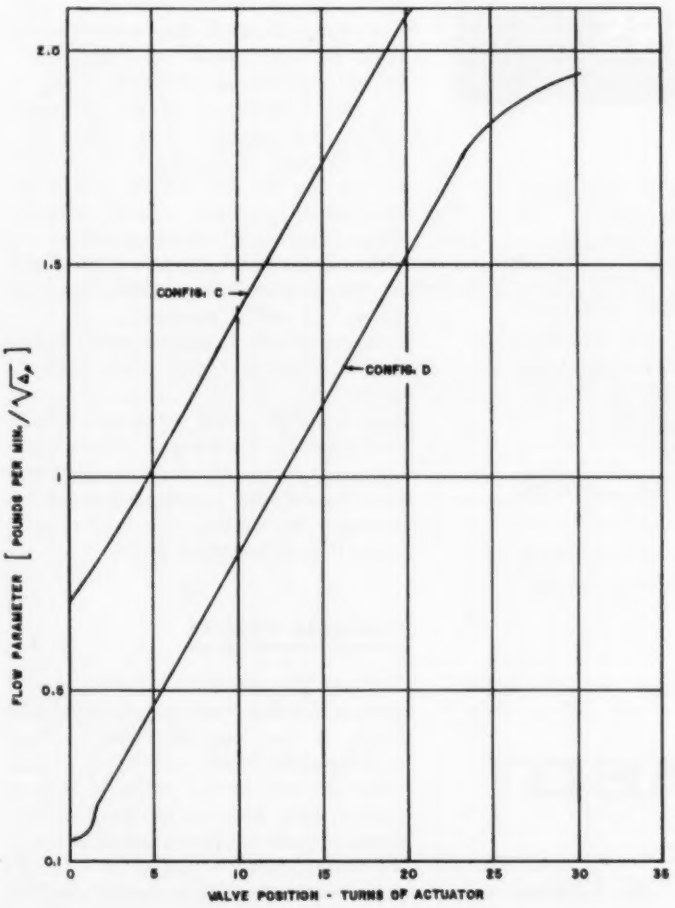


Fig 3 Flow measuring characteristics of the Yasui Variable Venturi valve for configuration *c* and *d* as shown in Fig 2a.

Fig 4 Variable Nozzle Flow Meter provides better than ½% accuracy and 500 to 1 flow range at much less cost than the more accurate variable venturi meter.

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measurement or control of flow over a wide range. Shaping the toric plug of the valve as shown results in a variable venturi in which the area of the orifice is proportional to the angular displacement of the plug, which in turn is proportional to the valve setting (see Fig 3). About 50 to 1 flow range may be maintained accurately with only one pressure gage, and pressure loss is one quarter that of a standard orifice.

The principle of flow measurement with the variable venturi is based on the same flow equations used in classical methods of measuring fluid flow:

$Q \approx AV$

where

Q = Quantity of flow

A = Area of orifice

V = Velocity of flow through orifice

Velocity of flow through the orifice is determined by measuring the differential pressure between the upstream pressure and the pressure at the orifice and applying Bernoulli's equation

$V \approx (2\,gh)^{1/2}$

where g = gravitational acceleration

h = differential pressure measured in height of liquid.

In conventional flow measuring techniques, since the area of the venturi orifice is fixed, flow measurement must be determined in terms of V, which requires equipment for computing the square root of the indicated differential pressure. But with a variable Venturi, V can be held constant by varying the flow orifice so that the differential pressure doesn't change. Thus the flow (Q) is measured by the orifice area (A) which, as we have said, is proportional to valve position (turns of valve actuator).

Automatic flow measurement is easily accomplished with the variable venturi by use of a servo system to hold the differential pressure constant at a prescribed set point. When properly calibrated, the system indicates flow directly by position of the valve actuator in relation to a dial calibrated in quantity of flow.

VARIABLE NOZZLE

Since the relation between orifice area and valve position was so ideally linear in the variable venturi, Yasui experimented with use of the toric plug in place of the critically shaped venturi plug to see what kind of flow measurement performance this much less expensive technique could achieve. He was surprised to find he

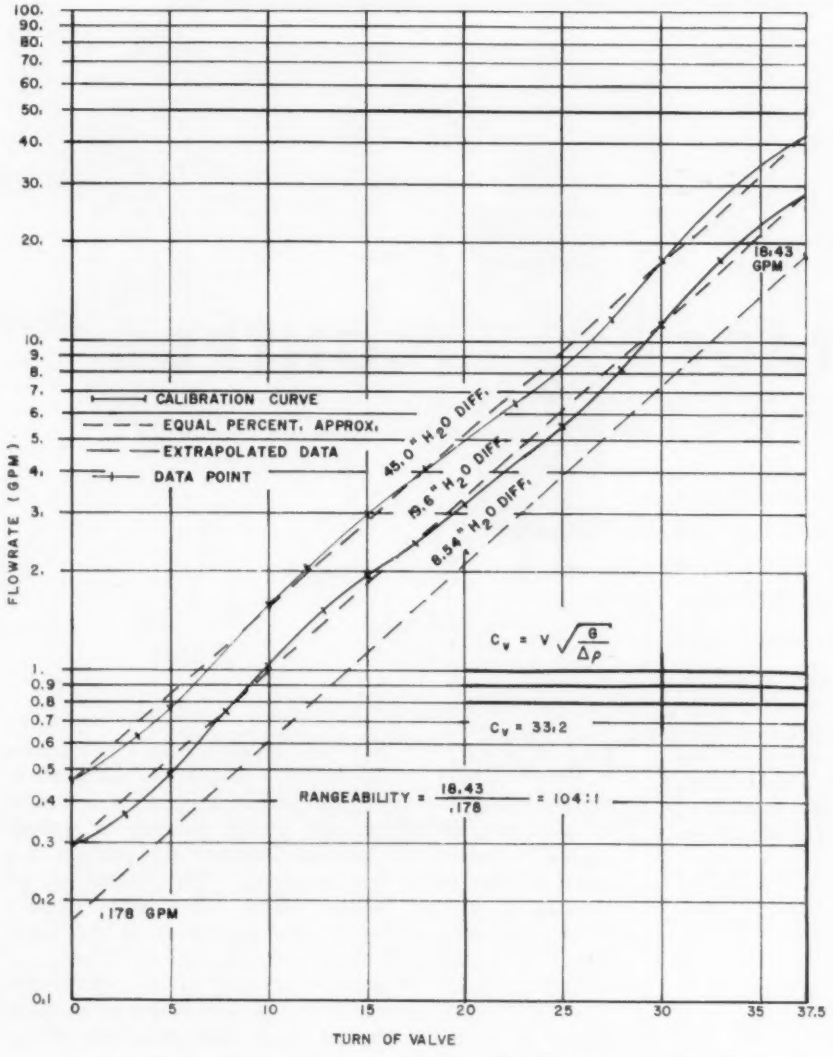

Fig 5 Flow measurement performance of a Variable Nozzle Flow Meter designed for the Foxboro Company. The performance tests were conducted and the curves were plotted by R. Briggs of the Foxboro Co.

could get ½% accuracy or better and 100 to 1 flow range with the simpler design.

The production model of the design is a very simple-to-operate portable unit called a variable flow nozzle. At a low set-pressure differential, the flow nozzle is calibrated throughout its entire range with the liquid to be measured. Turns of the actuator screw which retract the plug from the through passage are proportional semi-logarithmically with flow as shown in Fig 5. The calibration marked on a metal plate attached to the plug arm or to a calibrated plate at a remote location permits direct reading of flow in gpm or ppm or any desired units. With a 45-inch pressure differential, the flow range of the unit is 0.25 to 25 gpm of water. Larger pressure differentials permit greater flow ranges.

To read the flow rate, the handle is turned either in the open- or close-direction until the prescribed differential pressure is attained on the pressure gauge. Then the flow is read directly on the scale opposite the indicator.

The unit is equipped with accessible pressure taps parallel to the gauge, to provide for additional instrumentation and equipment or for safety interlock purposes. For example, a pressure transducer connected to a chart recorder could record fluctuations in flow. In the case of flow failure of coolants, a pressure switch could be made to turn off current or heat to protect equipment. It could also be used to turn on auxiliary standby equipment.

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*Patent Applied For

†It is possible to determine the accuracy of the VDR-106 to a certainty of 1 part in ten million using the Primary Standard ratio technique described in Precision Vol. IV No. 1. Copies are available upon request.

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HIGH VOLTAGE CONTROL

Electro-optical device consisting of a light bulb and a photosensitive cell contained in a light-proof case affords isolation up to 25,000 volts between light bulb (control) and photoconducting cell (signal) circuits.

by Martin Finigian,
Product Design Engineer
Industrial Components Division,
Raytheon Co.,
Newton, Mass.

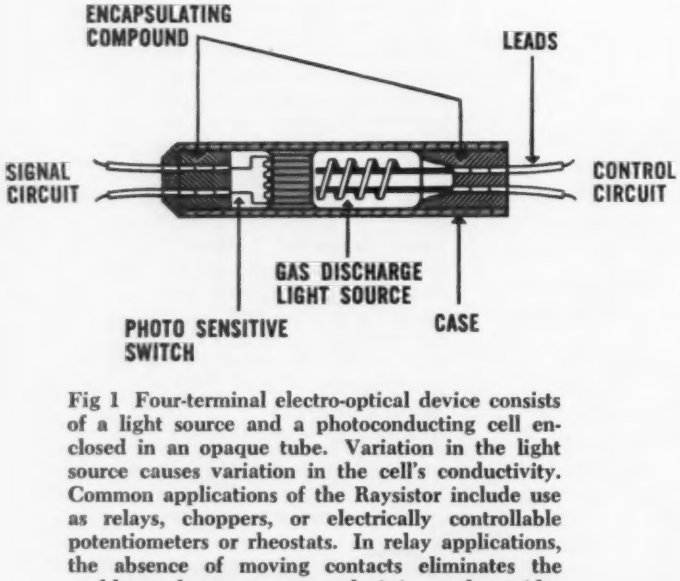

Fig 1 Four-terminal electro-optical device consists of a light source and a photoconducting cell enclosed in an opaque tube. Variation in the light source causes variation in the cell's conductivity. Common applications of the Raysistor include use as relays, choppers, or electrically controllable potentiometers or rheostats. In relay applications, the absence of moving contacts eliminates the problems of contact wear and pitting and provides life capability of over two billion operations. In potentiometer applications, noise and scratch of a moving contact in the signal circuit are absent. As a chopper, the Raysistor avoids the problems associated with moving contacts. Less than 0.5 microvolt emf is induced in the photocell due to modulation of the light source.

In July of last year, Raytheon announced a four-terminal electro-optical device called a Raysistor, designed to replace relays, switches, and potentiometers for low-noise commutation, switching, and circuit control. A voltage applied to two of the terminals controls the passage of a signal at the other two terminals. The control circuit consists of a light source which, when fully excited, lowers the resistance of a photoconductor in the signal circuit by a factor of about 10^6, thus allowing an ac or dc signal to pass. When the intensity of the light source is varied, the Raysistor acts as a potentiometer or rheostat. Figure 1 describes the physical characterisctics of the basic Raysistor design.

NEW HIGH-VOLTAGE DESIGN

A major factor in the performance of the Raysistor is the electrical and mechanical isolation of the control circuit from the signal circuit. Electrical control energy is converted to light energy to release charge carriers in a completely separate circuit. Raytheon engineers recognized that this principle could be used to provide extremely high voltage isolation between circuits. Applications of such a device would be for control of high-voltage power supplies, bias control of high-voltage regulator tubes, and metering of any circuit at a potential with respect to ground (with a meter at ground potential).

Starting with the basic Raysistor, Raytheon set up a development program to provide isolation up to 25,000 volts between the signal circuit and the control circuit. Figure 2 shows a production model of a high-voltage Raysistor that fulfills the program objectives. Figure 3 shows the performance of a typical unit.

Principal problems of the design were:

• *To find a dielectric material that would be a water-clear optical medium for maximum transmission of the control light, and that would not break down under high-potential gradients so as to permit spark flash-over be-*

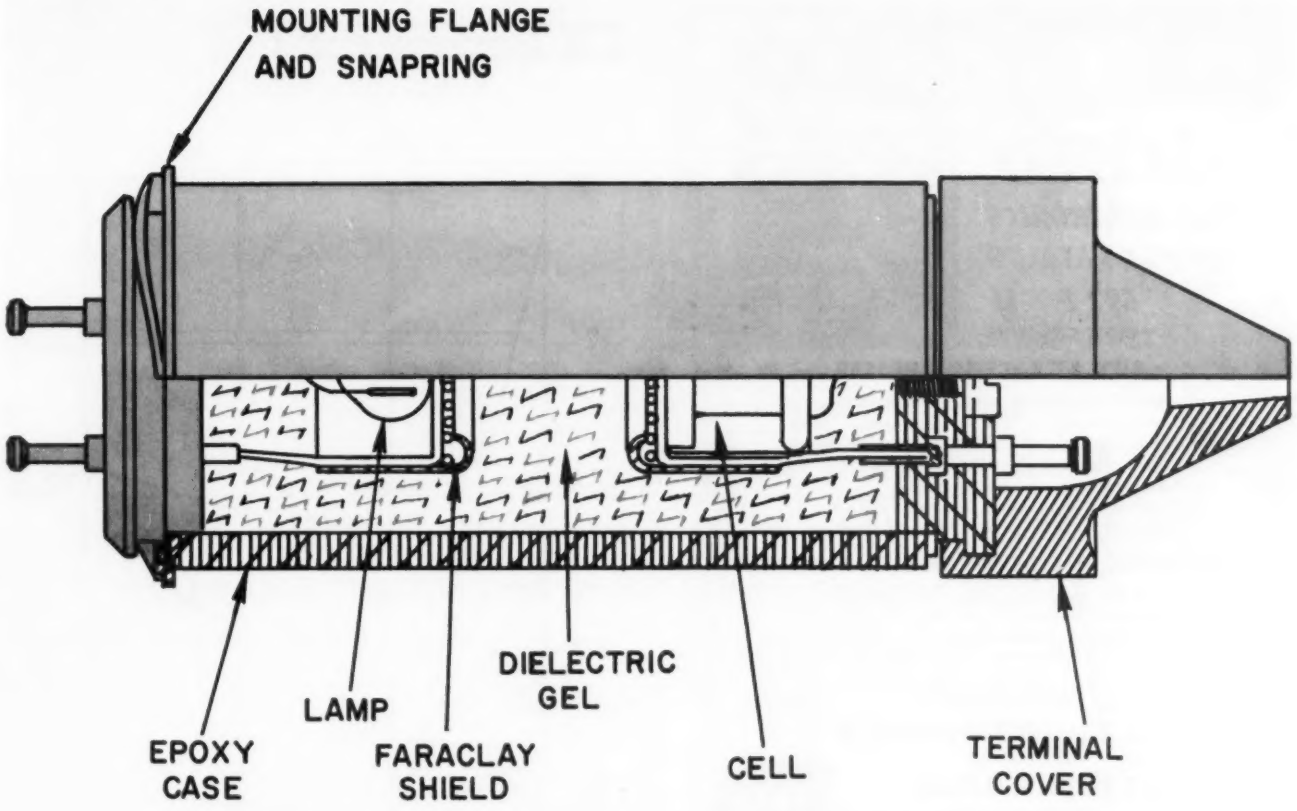

Fig 2 High-voltage Raysistor, encapsulated in a high-dielectric transparent fluid, operates with 25,000 volts differential between the control circuit and the signal circuit. Tentative specifications: control circuit is an incandescent lamp with supply voltage of 6.0 vdc or peak ac and control current of 0 to 200 ma; signal circuit is a photoresistor with on resistance 100 ohms, off resistance 4 x 10⁶ ohms, maximum power dissipation 250 mw, and maximum voltage 300 vdc or peak ac.

tween the control and signal circuits.

- *To prevent corona due to ionization of gases. Corona has two harmful effects: glow of the gases activates the photoconductor, causing error in the output; and the ionization products often lead to cumulative breakdown of the dielectric materials.*

THE DIELECTRIC MATERIAL

A survey of dielectric materials and experimentation with many types indicated availability of a gel that provides the necessary optical and dielectric properties as well as the desired temperature characteristics.

Stiffer, unyielding materials were found to be unsatisfactory because they tended to transmit forces caused by temperature variations to the embedded parts, and even to stress-crack themselves at low temperatures. The dielectric gel also provides a high degree of shock and vibration protection to the circuit components suspended within it.

To prevent formation of air bubbles which would tend to ionize in a high electric field, causing corona glow or spark flashover, the gel is introduced into the assembly under vacuum and is heat cured so that it adheres to all surfaces contacted, preventing any air gaps at the interfaces. The gel maintains contact with all surfaces indefinitely. Its properties are stable over a wide temperature range and over a much longer time than the life of any equipment in which the Raysistor would be used. The intimate surface contact of the gel, together with good thermal conductivity (uncommon in electric insulators), provides good heat transfer, allowing the photocell to be rated for a much higher power dissipation than would be possible in air.

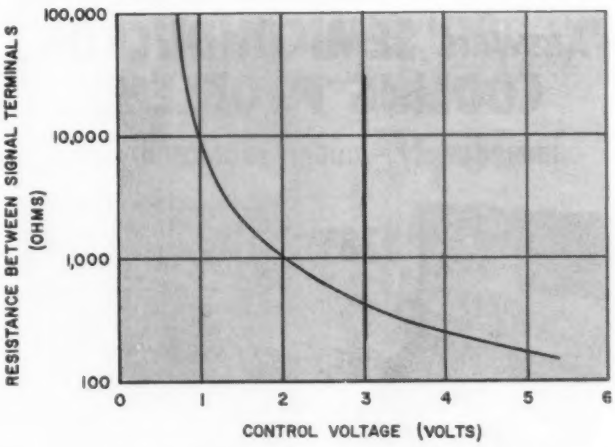

Fig 3 Transfer function of type CK1108 High-Voltage Raysistor. A wide range of specifications is available for potentiometer or control link applications. The curve shows a signal resistance variation of 10,000 to 1, with a 10-to-1 range of control voltage. Models with full control voltages as low as 1.1 volts are available for use with transistors.

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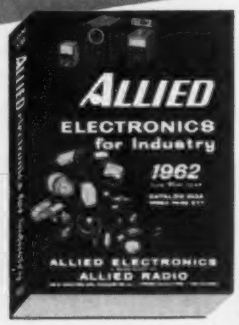

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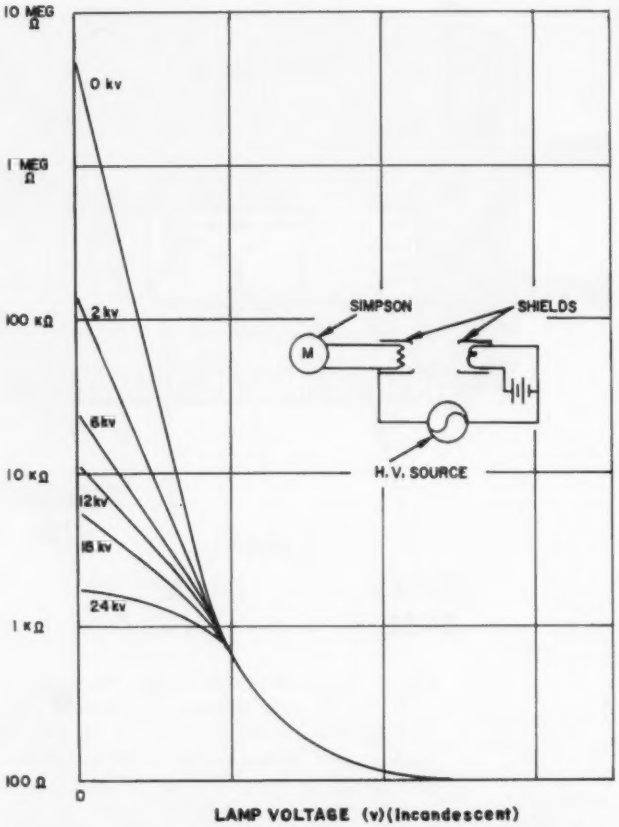

Fig 4 Performance of the high-voltage Raysistor without wire-mesh closures over the openings in the corona shields. Penetration of the electric field into the enclosures causes gas in the cell or bulb to ionize. This effect is apparent from the change in cell-resistance-vs-lamp-current curves as voltage from the high-voltage source is increased.

CORONA SHIELDS

Ionization of gases within the light bulb and the photocell is prevented by surrounding the bulb and photocell with corona shields. The two shields, which are identical, are cylinders with one open end rolled into a torroidal shape to minimize corona formation points. Across the opening in the torroid is a wire-mesh screen to prevent penetration of the high electric field into the shield enclosure, so that both the bulb and the cell are maintained in a field-free space.

Early tests without the wire mesh showed definite changes in the lamp current vs cell resistance curves as the high voltage was increased (see Fig 4). These changes were attributed to ionization of gases in the bulb or the cell caused by penetration of the field into the enclosure. Figure 5 shows how the wire mesh screen eliminates field penetration and improves performance. The shield assembly also serves as a true Faraday shield, minimizing capacitive coupling between the lamp and the signal circuits. This prevents ac voltage appearing across the lamp and signal circuits from being coupled into the signal circuit.

OPAQUE ENCLOSURE

Since the resistance-vs-light-intensity curve of the photocell is logarithmic, a very small amount of light has a

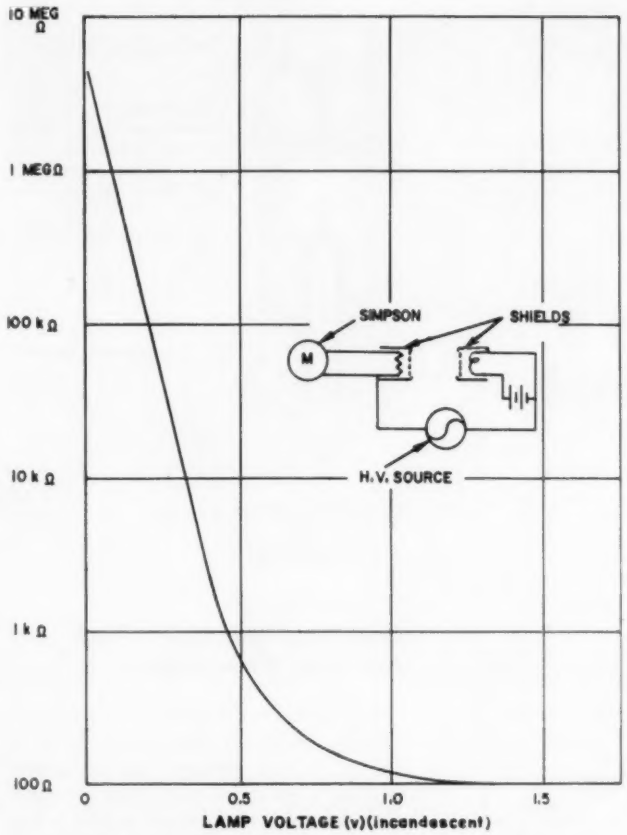

Fig 5 Performance of the high-voltage Raysistor with wire-mesh closures over the openings in the corona shields. The screens prevent formation of electric fields inside the enclosures, preventing any variation in performance as voltage from the high-voltage source is increased.

pronounced effect on photocell resistance. An absolutely light-tight enclosure for the unit was therefore required to protect the photocell from interfering light. In addition to being absolutely opaque, the enclosure had to be dimensionally stable and non-hygroscopic and have very high dielectric strength. This combination of properties was hard to find. Most dielectric materials assumed to be opaque were found to be unsatisfactory under test. The problem was solved by a special filled epoxy formation which meets all requirements.

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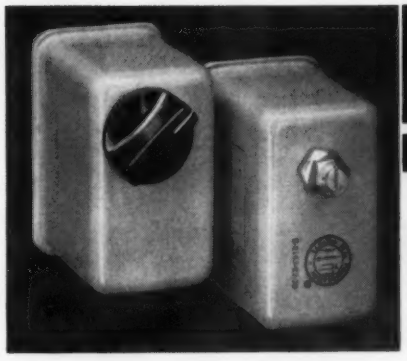

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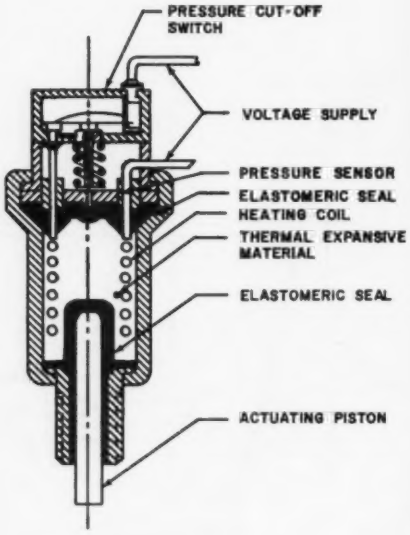

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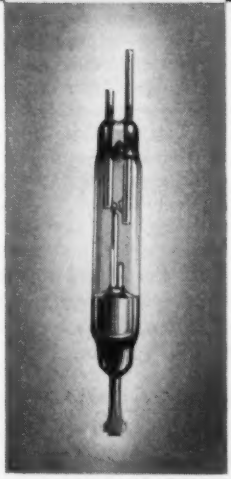

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TRANSISTORIZED MACHINE CONTROLS

Demand for faster and more complex machine operations and information handling plus improved reliability of semiconductors prompted use of transistors in place of magnetic devices for industrial switching and control.

To give machine control specialists a system that is (1) lower in cost and less complex for easy maintenance as compared to a magnetic amplifier control system, and (2) higher in operating speed and life expectancy as compared with relay control equipment, Delco Radio engineers established a development program for a transistorized static control system based on the following major design objectives:

- Economical reliable static control circuits that operate under wide supply voltage variations and adverse environmental conditions.
- Logic modules that can perform any conceivable machine control using simple programming procedures.
- Low cost power supply module that delivers power to operate all logic modules while maintaining safety and interlocking protection to prevent false operation of machine load members.

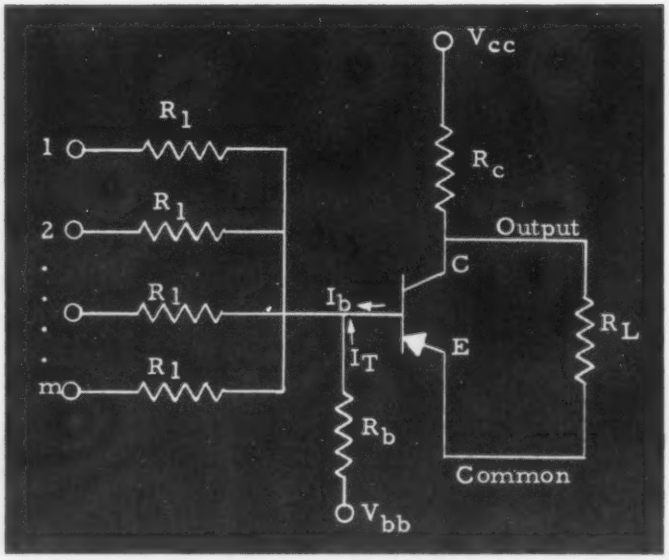

Fig 1 Appropriate input coupling networks and operating points, speed of response, output power level, and operating temperature range were the important parameters in designing this transistor NOR circuit (3-input inverter). Any device behaving as a switch dissipates a minimum of power in either the steady ON or OFF condition as contrasted to a partially transmitting state. Low power dissipation and temperature rise of Delco's junction transistor, in either the ON or OFF state, gives the circuit high reliability. D. G. Wilson of Delco pointed out that for the simplest over-all system design, all logic should be performed by sensing discrete and steady signal levels. For this purpose, he said, direct coupling would be best since the least amount of signal manipulation is required. Thus, the circuit presents a very low input impedance to signal currents flowing into the base connection. Furthermore, the voltage drop from base to emitter necessary to make the transistor fully conducting is also very low because of the high transconductance of the device. To apply two or more input voltages with a minimum of cross-coupling, it was necessary to connect a relatively large resistance from the base to each signal source. The circuit shown here has "m" signal inputs, each coupled to the transistor base through a large resistor R_1. Selection of the desired number of inputs is somewhat arbitrary. However, experience has shown, Wilson stated, that 3 input logic devices accommodate a great majority of machine control requirements. After becoming familiar with system input and output power requirements of machine control, engineers at Delco chose 1/10 of a watt for logic operations. At this level, dc power requirements for the logic would be relatively small and thus simplify power supply design. Yet the output signals can readily be amplified up to useful levels.

ELECTRONICS PROBLEM

One of the major design problems, reported by A. E. Vyzral, Mech. Engr. and J. E. Calabro, Elect. Engr., involved the development of a basic NOR circuit that withstands many parameter and power supply variations while operating at a sufficient power level to hold output amplifier or inductor circuit requirements to a minimum. Their solution was to sacrifice a large number of inputs and outputs but retaining enough for a reasonable number of logic functions. Where a greater amount of inputs is required, diode OR circuits can be used.

Basic NOR circuit, described in Fig 1, is essentially a 3-input inverter. Since the common emitter transistor amplifier effects signal inversion, it, therefore, became a matter of selecting appropriate input coupling networks and operating points to obtain the desired circuit.

MECHANICAL PROBLEM

According to D. G. Wilson, a member of Delco's Industrial Electronics Group, earlier designs of static control systems were built up in conventional electronic rack mountings. Logic circuits were on printed circuit boards with connectors attached to one edge. However, this was found to be very awkward because of the difficulty in making logic changes on the connector side of the rack.

Engineers at Delco studied the various forms of packaging and wiring with the prime objective of ob-

Fig 2 Logic card rack enclosure, of Delco's machine control system, accommodates any arrangement of twenty cards consisting of 3-input transistor NOR, 4-input diode OR, memory, timer (adjustable from 0.1 to 1 second) and power amplifier (20 or 50 watts) circuits.

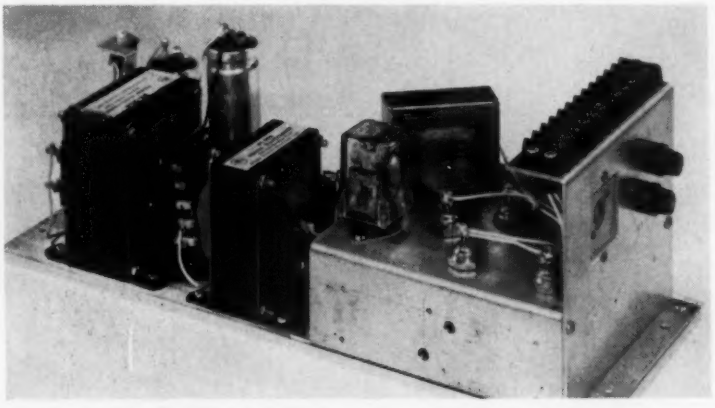

Fig 3 Semiconductor components are used throughout Delco's power supply module for their static machine control system. Both 5.6 and 12 volt outputs (logic and bias supply) are regulated against line voltage variations of 100 to 130 volts ac and the full range of loading. 12 volt section uses a one stage transistor regulator following a Zener voltage reference element. Since this circuit provides maximum negative feedback to the transistor, long term performance is virtually guaranteed, according to D. G. Wilson of Delco. Zener reference circuit directly supplies the 5.6 vdc bias. To prevent system malfunction, two other transistors are used in conjunction with 2 relays for safety interlocking circuits. These transistors both operate in the switching mode. Use of relays is indicated here, since in one case, complete circuit isolation from the ac line is demanded, and in others, use of additional transistor switches to replace relay contacts would make the circuit overly complicated. In normal operation, these relays are continuously energized. Rectifying the output of an isolation transformer gives the high voltage necessary for exciting switch input devices. This voltage is nominally 120 volts dc; however, it will vary since no regulation is employed. In order to prevent false operation of memory and timer elements, the 120 volt potential is applied to the switch circuits when power is initiated. A time delay relay circuit then allows a 1 second delay before applying collector supply voltage to the normally off sections of memories and timers. Relay also breaks the 24 vdc to power amplifiers to prevent false operation of load members during the delay interval. To protect against the loss of the 5.6 vdc bias voltage, a transistor is connected in parallel with the time delay relay and biased to non-conduction by the bias voltage. If this voltage falls below 3 volts, the time delay relay de-energizes, cutting off the power. Also, the time delay relay interlocks the line-holding relay circuit. This circuit consists of a transistor with a relay in the collector circuit which obtains excitation for the output side of the time delay relay. For normal line voltages (above 100 vdc) the transistor is forward biased, allowing relay energization. Contact on this relay is in series with the input ac line. If the line voltage drops below 90 volts ac, transistor turns off and drops out the line-holding relay. Thermostatic switch, in series with the input line, opens at 160°F to prevent possible erratic operation of the system.

taining a rigid assembly enclosure that would contain the functional circuits (individual logic, memory, timing and amplifier circuit modules) and the means for supplying them power, while enabling the user to conveniently program and remove the modules.

Their solution was an enclosure rack (Fig 2) with plastic slides as module holders. Twenty of these modules plug into a mother board, at the bottom of the enclosure, to receive power. Programming of each card module is accomplished through taper pin terminal blocks on the top of the cards. Open top enclosure provides easy removal of the cards.

LOGIC CIRCUIT MONITORING

To hold costs to a minimum and still maintain maximum reliability, the engineers came up with an indicator circuit that requires negligible input power using only one stage of amplification. They designed the circuit around a small, low current incandescent lamp operating from the logic supply voltages. (This type of indicator circuit is used in their input and output monitoring modules.) The lamp lights when a logical "1" is applied to the input, which presents a load equivalent to any logic element input. The twenty logic monitor circuits easily mount in a card rack. To mate with twenty functional circuits, this mounting rack fastens, by slide buttons, to the plastic wiring duct of the basic functional module.

INPUT DEVICES

Choice of compatible input devices to indicate machine conditions for static control is a controversial subject, Wilson believes. Many people feel, he explained, that for those processes for which static control is being considered, static sensing devices should also be specified. Wilson agreed that this was desirable, but unfortunately, he pointed out, such devices have not generally reached the performance levels possessed by mechanical switch devices. In discussing switch life, Wilson described the role it plays in Delco's static control system.

Life and reliability of input switches of all types, but especially limit switches, have been the cause of much concern, he said. In present relay machine controls, the switch is often required to carry heavy contactor or valve currents and although the switch is rated to handle this inductive load, its life is generally limited by the wear of the contacts, Wilson stated. In certain cases, this switch current can be reduced by in-

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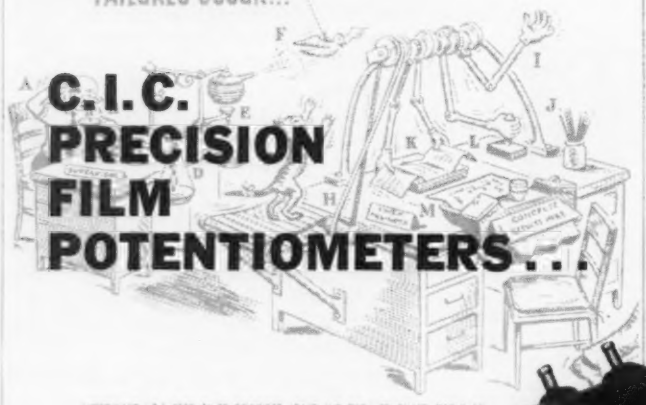

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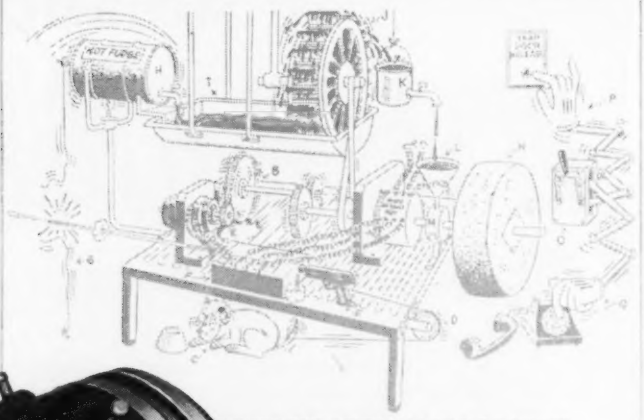

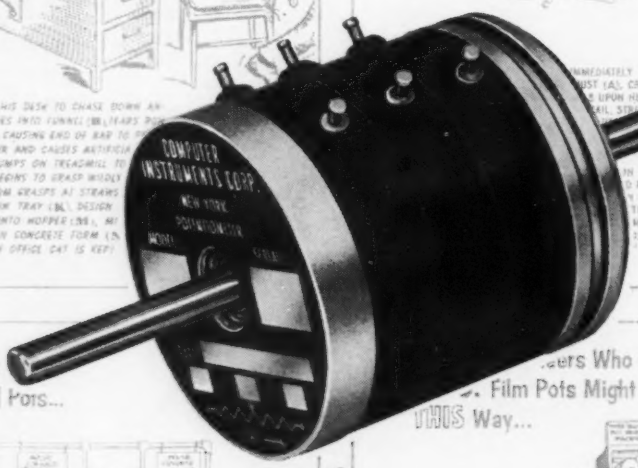

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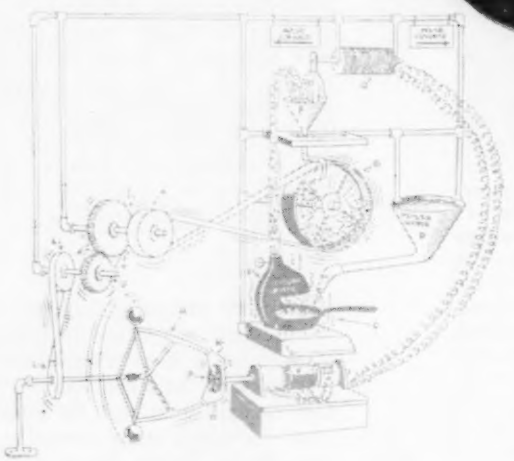

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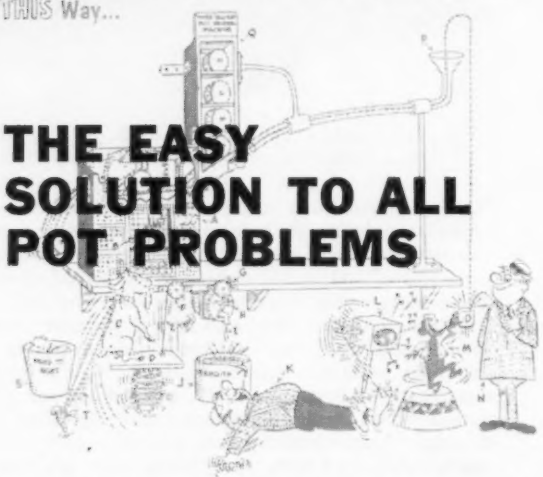

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terposing a relay to handle the load current. This means additional expense and does not necessarily achieve a great increase in overall reliability, Wilson believes. One of the principal advantages of static control is the tremendous increase in switch life, he declared. This is mainly due to the fact that the switch only has to handle a few mils of current or roughly 1/1000 of their rating.

Early in the development of transistor static control, the Process Development Section, at the request of the Delco engineers, made studies to determine the optimum voltage and current for limit switches. Results of this study showed that full mechanical life of the switch is realized for a dc switch voltage in the range of 100 to 150 volts and currents of less than 10 mils. These tests further established that many industrial limit switches have a mechanical life of 50 million operations.

Several different makes of switches were life-tested under these conditions. They were cycled to mechanical failure and when opened for examination, the contacts were like new. From these tests, Wilson concluded that the use of high dc voltages is superior to lower voltages because of the increased ability to burn away any high resistance oxide tending to form on the contacts. Therefore, he said, transistor static control, in addition to eliminating relays handling up to 100 watts, greatly enhances switch life.

For the above reason, Delco uses a dc voltage of about 120 volts from its power supply to obtain signal currents from machine input switches. Resistance of about 30,000 ohms is put in series with each logic element input for which a switch input is required. If a particular switch device could not withstand this potential, then the lower supply voltages can be used.

Photocell units of the photoconductive type, in Delco's system, provide a signal which is sufficient to drive a NOR unit directly without preamplification. This feature, Wilson said, eliminates a cumbersome relay amplifier unit normally required for machine control. Similarly, sensitive pressure switches and probe contacts work directly into transistor static control units without additional amplification.

GENERAL SYSTEM DESCRIPTION

Discrete electrical signals, either a voltage or no voltage, triggers the Delco static control system into action performing logical, memory and amplification operations. Control outputs energize electromechanical elements such as air or hydraulic valves, solenoids, contactor relays or clutches and brakes.

Typical Delco control system consists of five basic modular system units: signal converter, the functional logic circuit module, the logic monitor module, output terminations/monitor module and power supply unit.

To prevent false operation of machine load members, the power supply module, described in Fig 3, provides safety and interlocking protection. Power supply de-energizes under the loss or reduction of: bias voltage of 3 vdc, ac line voltage below 90 for longer than 2 seconds, external switch supply voltage of 90 vdc, and logic supply of 6 vdc. Also, an increase of ambient temperature above 160°F will cause power supply cut-off.

In addition to fulfilling their development goals of high operating speeds, low cost, simplicity of design and increased reliability, engineers at Delco believe that the system offers the versatility required for today's complex machine and process operations.

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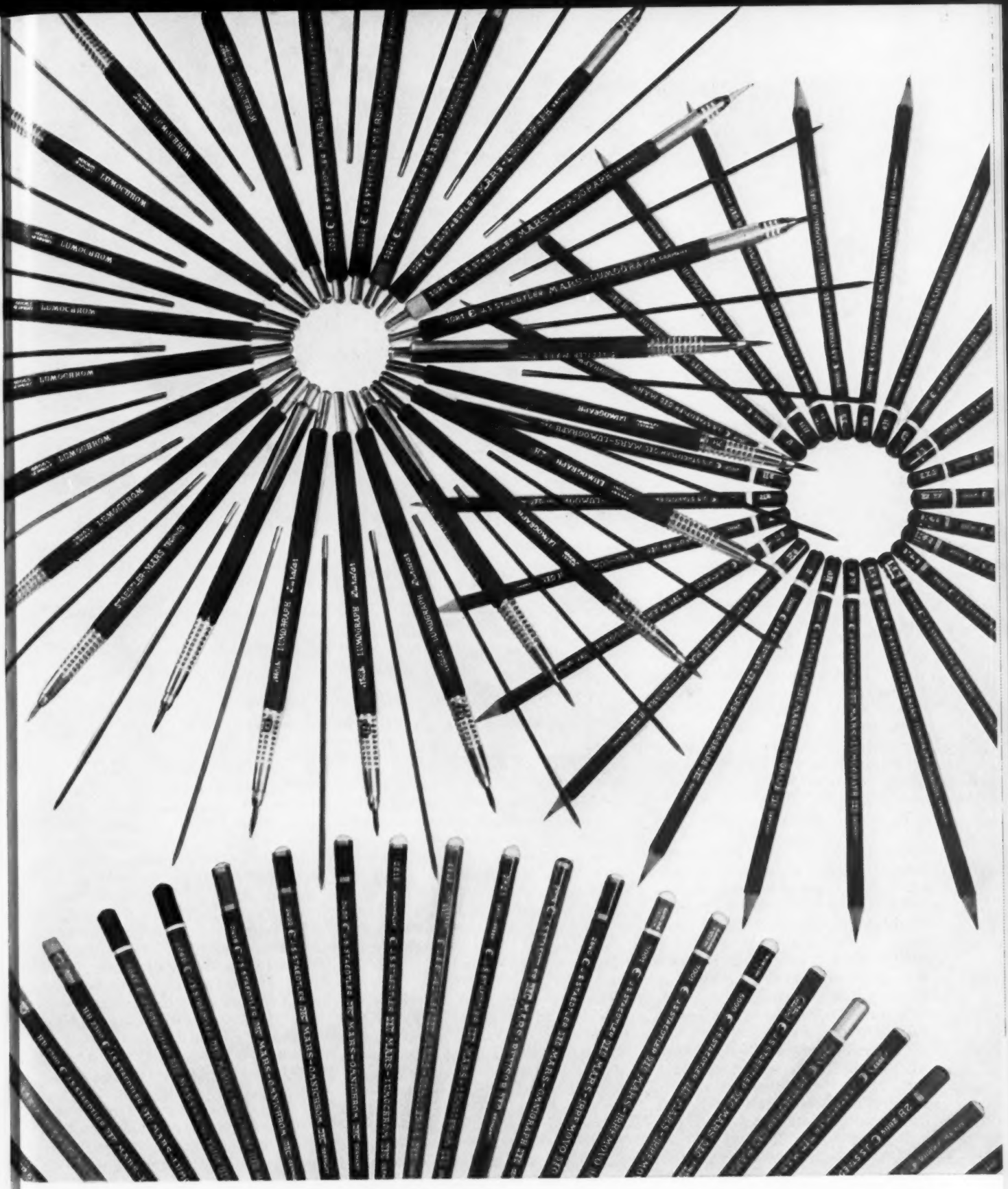

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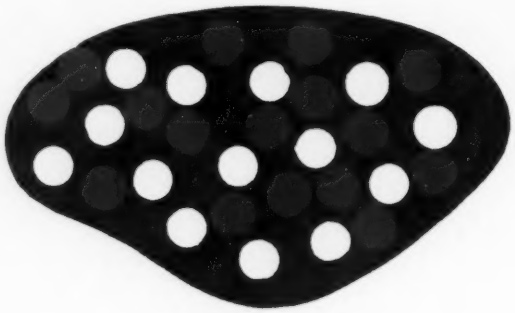
SURVEY OF MOTOR INSULATIONS



Standardization on Higher Temperature Levels Envisioned

Discussing the thermal endurance of motor insulations in a paper presented at the 1961 ASME Design Engineering Conference, Frank C. Rushing, Mgr., Motor & Gearing Engrg. at Westinghouse Electric, traced the development of the major types of insulating materials and examined its effect on industrial motor standards. An abstract from his talk, presented here, constitutes, we believe, an excellent survey of these important materials.

Most industrial motors have conservatively designed insulation systems for the duties imposed on them. Loadings vary widely, and it is the integrated time-temperature influence which affects the life of motor insulation. In actual practice, Rushing states, the great majority of motors have thermal lives of fifteen to twenty years.

INSULATION REQUIREMENTS

Located at the very heart of the motor where the forces are produced, insulation occupies valuable space. In the motor slots, it occupies as much space as the conductors and half as much space as the "bottleneck" sections in the iron circuit. Obviously, for economy of design, insulations should be as thin as possible.

The mechanical structure of an insulation system is strongly affected by varnish. For example, Rushing notes, when a glass fabric-varnish combination is used for conductor insulation, the mechanics of a failure can involve varnish deterioration at excessively high temperatures, allowing the conductors to move and vibrate, thus wearing away the glass and allowing voltage breakdown. Or, he adds, if in a moist chemical environment the varnish deteriorates, the moisture and chemicals can penetrate the glass fiber and produce leakage paths leading to ultimate electrical breakdown. Therefore, good insulation systems require good varnishes for the temperature classification being used.

Heat is generated in the copper and iron as well as in the bearings and cooling medium; but the greatest amount is in the copper and iron. Alternating magnetic flux in the iron and electric current in the conductors produce heat. In open motors, outside air is blown over the conductors and iron to carry away the heat. In enclosed motors, heat is carried away from the outer housing surface, requiring conduction through longer paths from the source of generation to the area of dissipation. Thus, Rushing concludes, the open motor is easier to cool. The motor design and application engineers work for optimums of heat-generation control, heat-dissipation ability, and protective-enclosure requirements to produce the most economical solution for each application.

By allowing higher temperatures and using insulation of correspondingly higher temperature stability, Rushing declares, higher ratings can be obtained from totally enclosed fan cooled (TEFC) motors. For example, according to the NEMA standards for 10-hp ac motors, the open motor produces 15 percent more horsepower than the TEFC motor for the same life with essentially the same electrical parts and insulation. But, deviating from this standard and allowing the TEFC motor an additional 15-deg C temperature rise and providing correspondingly higher temperature insulation, its output could be increased to the same as the open motor and the life would be the same, Rushing stated.

Many standards call for capabilities of operation under adverse conditions which increase the motor's operating temperatures above the normal:

- Plus or minus 10 percent voltage range will produce higher magnetization at higher voltage with resulting increased saturation of the iron and increased iron losses. At low voltage, the load currents are increased and give increased copper loss.
- Locked rotor or stalled time must be allowed. It varies with size of motor and application, but 10 to 20 seconds are frequently required on small sizes. The copper losses have to be low enough to avoid excessive insulation aging and even melting of the conductors.
- Fifteen percent continuous overload capabilities are built into most standard drip-proof motors in line with NEMA standards.

After noting the above requirements that insulation must meet, Rushing describes the development of

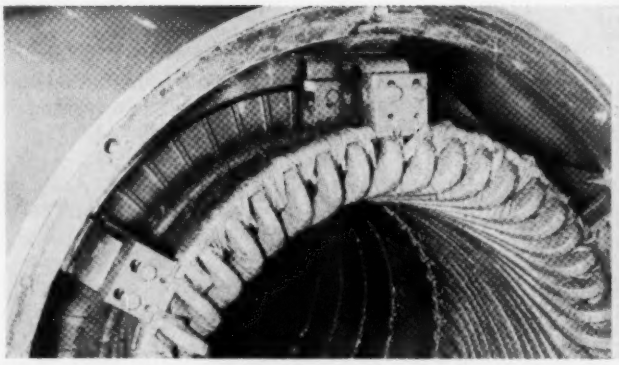


Fig 1 Thermalastic insulation, a mica and solventless polyester Class F system with outstanding moisture and chemical resistance.

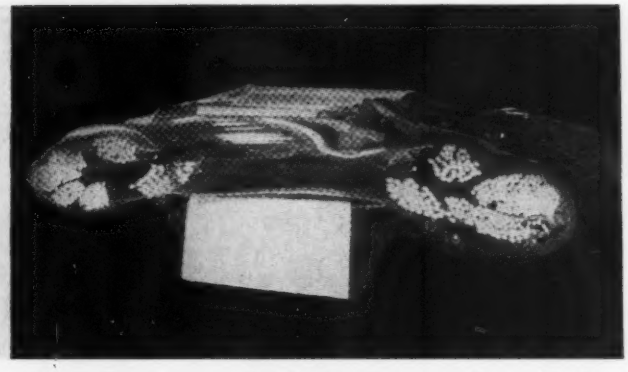


Fig 2 Epoxy encapsulated Class B system for application in moist, chemical environments.

motor insulations as follows.

VARNISH

Oleoresinous varnishes, the mainstays for motor winding impregnations for many years, did a fair job of sealing against moisture and contributed to the mechanical strength of the winding structure. They were used for 105 C (Class A) and 130 C (Class B) temperatures.

Then, according to Rushing, came the thermosetting varnishes of the phenolic type which have better bond strength while hot, are less sticky, and withstand chemicals and oil; some are good for 155 C (Class F).

Polyester in solventless form came to provide improved impregnation and mechanical proerties to give better electric strength, and better resistance to moisture and chemicals. It is used, also, for molding and encapsulating. Some are suitable at 155 C (Class F) temperature. Extensive application has been carried out with the well known Thermalastic insulation system, Fig 1.

An important addition was epoxy which has improved bond strength and improved alkali resistance. It is available in both solvent type and solventless type. The latter can be obtained in varieties to use for encapsulating, Fig 2, or casting into heavy wall thicknesses. Epoxys are used for 130 C (Class B) and 155 C (Class F).

Silicones were then applied to advance temperature levels up to 180 C (Class H) and 200 C. They are used widely as solvent-type varnishes, but are also available in solventless form. They have also been produced in rubber form for somewhat lower temperatures and are used in motors to give good moisture and chemical resistance.

WIRE INSULATION

Fiber and Paper Coverings. Cotton was used for the early wire insulation. It was suitable for 105 C (Class A) temperature. Asbestos coatings first served for higher temperature, Class B (130 C), insulation. Glass fiber covering came to improve mechanical properties and to reduce the insulation thickness. More recently, Dacron has been used with glass to further improve mechanical features and to enable further reductions in thickness.

Enamel Insulation of Wire. Over 20 years ago, oleoresinous enamel was used for wire insulation. Then, a significant improvement was made with a poly-vinyl-formal enamel to produce Formvar. It is a 105 C (Class A) wire insulation with good mechanical and dielectric properties. It is much more rugged than fiber insulation and consumes only one third the space in practical use.

A polyamide known as Bondar was later produced to provide higher temperature operation approaching 130 C (Class B). Polyesters have been provided to gain still higher temperature levels, up to 155 C (Class F), with good mechanical and dielectric properties. Epoxy has been applied in wire-enamel form to give improved chemical resistance.

Modified silicones have served for wire insulation to give temperature capabilities up to 180 C (Class H). Teflon is available for temperatures in excess of 200 C. Aromatic polyamides, Rushing believes, are now looming as practical candidates for wire enamels with good mechanical characteristics and usable above 200 C.

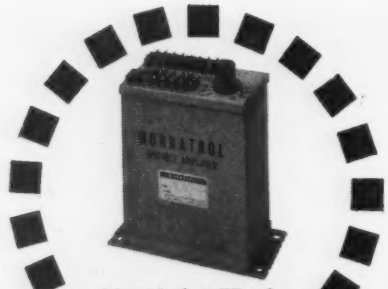
Fabric plus Enamel. To provide the ultimate in practical wire insulation, glass serving sometimes is used over enamel. It gives improved electric strength, provides spacing and mechanical protection for the enamel, and holds varnish to give a good mechanical structure. It is used at the expense of extra insulation space and is economical in certain severe applications.

Ground Insulation. Dielectric films and spacing have been used for ground insulation. Varnish films in combination with cotton, glass, asbestos, and mica have been used extensively for appropriate levels of temperature.

Paper in high-density compositions with some varnish as a binder is extensively used for 105 C (Class A). It provides spacing and electric strength. Commonly used are fish paper and rag paper. Usually used in combination with other materials which serve to increase the electric strength, paper has desirable physical properties for handling and for contributing to the mechanical structure of the insulating system, Rushing stated.

Mica flakes and mica paper are used as high-temperature ground insulation. In practice, this flake insulation is supported on glass cloth, paper, or film, and the combination is held together by varnish. It gives good electric strength, Rushing notes, and serves as the strong link in the system giving dielectric protection even after the varnish may have deteriorated as a result of aging at high temperature.

Mylar, a synthetic film, has been a boon to motor ground ihsulation, Rushing believes, particularly for the lower voltage classifications. It has greatly improved mechanical properties and higher electric strength as compared to paper and impregnated fabrics. Often it is used in combination with other materials such as Mylar-paper or Mylar-mica.



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MATERIALS

Silicone rubber, as a dielectric film for ground insulation, is usually applied as semi-cured tape and is consolidated by heat and pressure.

Improved temperature stability of treated paper is offering possibilities of further choices for insulation systems. Urea-treated paper is being used for higher than 105 C (Class A) temperatures in transformers; papers of the aromatic polyamide family offer possibilities up to 200 C.

FUTURE MOTOR TEMPERATURE LEVELS

Rushing believes that the use of high-temperature insulation is increasing. This trend is indicated by the recent NEMA standardization on 130 C (Class B) temperature levels in dc motors and in various derivative lines; for example, wound-rotor induction motors.

More of the specialty lines, Rushing observes, are coming out with 130 C (Class B) temperature; for example, encapsulated small integral horsepower motors, which have appeared in the past three years, use Class B. This was a case, Rushing explains, where, working copper and iron up to their capabilities pushed the heat higher than 105 C (Class A) temperatures and it was not practical to cool to 105 C. Therefore, Class B insulation was used and the temperature allowed to go to 130 C levels.

Users, Rushing declares, are demanding more and more special motors, which opens the door for application of higher temperature in special cases for reasons of economy. On the other hand, he adds, a great many standard motors are used, especially ac motors.

Looking into the immediate future, Rushing predicts: "Use of higher temperature insulation economically in standard NEMA ac motors will involve rerating motors to produce more horsepower with a given size. Such a rerating would have to be nationwide; it would have to be spearheaded by NEMA; and it would require the acceptance of users. In 1952, there was a rerating of ac standard which resulted in over-all economies, although it did not involve changes in temperature classes. The next such move, I predict, will involve use of Class B insulation (jumping beyond the present European practice which has established the use of 120 C [Class E]temperature level) and will entail giving insulation life equivalent to the present-day insulation life in USA practice."

Looking into the more distant future, Rushing concludes: "The use of Class F (155 C) insulation and temperature levels on standard ac motors brings into sharper focus other limiting influences. The present-day basis for rating would not be optimum for the higher temperatures. For example, present standard torques determine usage of a certain amount of copper and iron, and some motors would not require the allowed high temperature; this is a case where torque and not temperature sets the motor size. Other performance characteristics are similarly involved. Another important factor will be the economic handicap of higher electrical losses due to increased conductor resistivity at higher temperatures. This will be of significance in operating costs and be an offsetting factor to other economies resulting from material savings. It is predicted that Class F insulation will grow in usage through special and definite purpose applications, to certain specific segments of a line where temperature is a limit, and for increases in insulation reliability; but use of 155 C (Class F) temperature levels across the board for standard ac motors is not envisioned in the foreseeable future." • •

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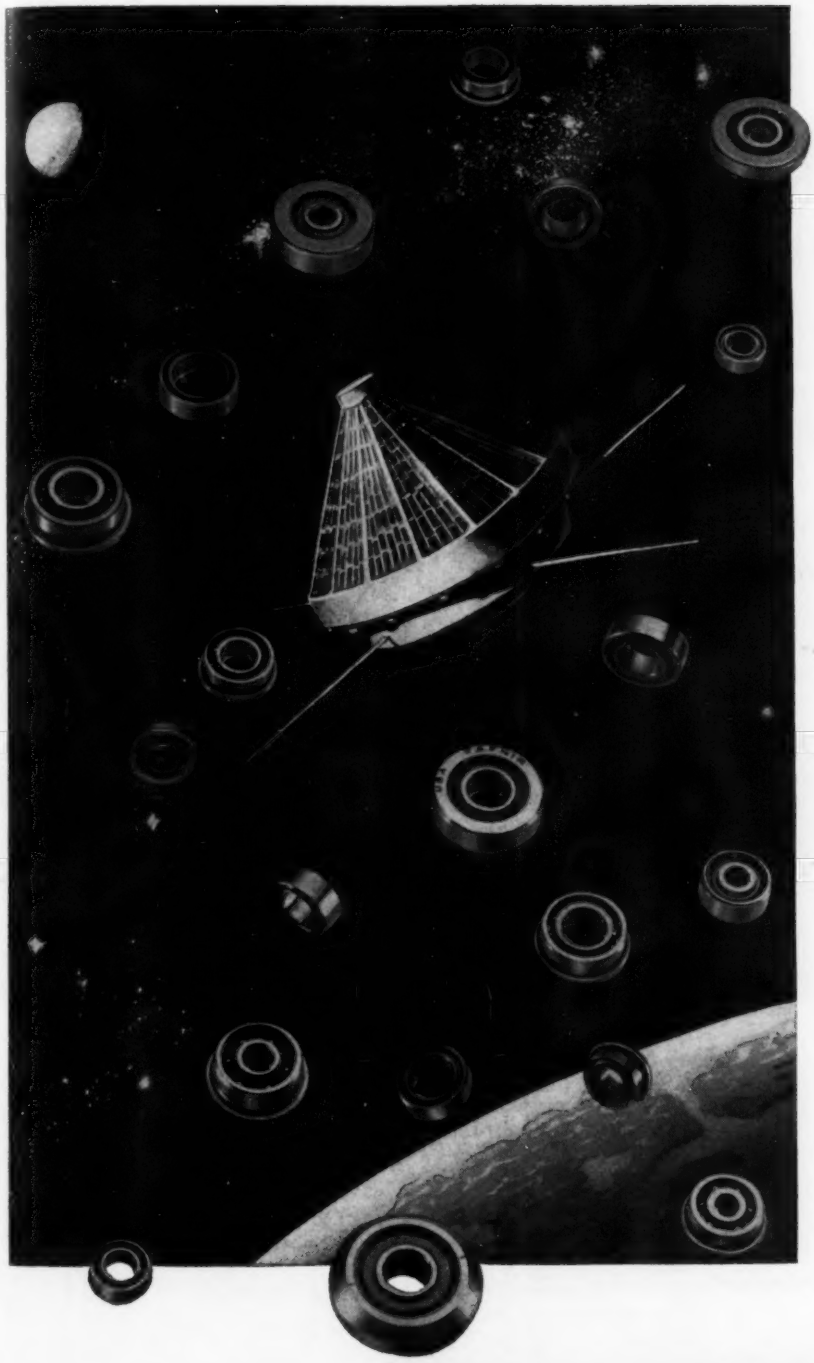

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H. T. Gruber, Battelle Memorial Institute, Columbus, Ohio

AN ANALOG APPROACH TO RELIABLE TRANSISTOR CIRCUITS

A large void in present knowledge of transistors is how to determine design requirements for overvoltage and overload protective devices. Here's an economical solution through use of thermal modules.

No matter what the initial cause for transistor malfunction or failure, the final cause is almost always too much heat dissipation at the transistor junction. Junction heating is caused by the power dissipated at the junction. Naturally, we limit the applied voltage to some level below the junction breakdown level. What about the current? How much current can we push through a transistor junction during a given period of time? The limiting factors are the maximum junction temperature rise we can tolerate and how fast we can remove the heat from the junction. If we know the junction temperature-rises produced by various forms of power input, we know one important limiting factor of transistor operation. Limiting the peak junction temperature to a safe level will help reduce transistor failures and operating parameter degradation. The result must be more reliable transistor circuits.

TRANSISTOR THERMAL ANALOG

Measuring junction temperatures under closely controlled conditions is very difficult and time consuming, and the conditions probably will not duplicate the operating conditions of interest. Theoretical thermal analysis of the transistor involves much arithmetic drudgery or the use of a sophisticated computor. A more economical solution to the problem may be obtained through use of a thermal model of the transistor. Solutions more accurate than those attainable with an analog are not justified, at the present time, because of the variability among transistors even within the same 2N type number. Development of this analog method was carried out under Bu Ship Contract NO bsr-77579.

The first problem in the construction of a transistor thermal analog is the determination of an equivalent circuit and the necessary circuit constants to represent the thermal circuit of the transistor. We shall consider two possible circuits: the transmission line equivalent circuit and the series string of parallel RC pairs equivalent circuit.

Transmission Line Equivalent Circuit. The transmission line equivalent circuit is made up of RC tee sections. Transmission line circuit constants may be computed from the geometry and the materials of the transistor. Here lies the major advantage; it is not necessary to have the actual transistor to perform a thermal analysis. This equivalent circuit could be very useful to transistor manufacturers. A disadvantage of the transmission line circuit is the unknown thermal properties of the welded or soldered joints. A transmission line circuit we considered using is shown in Figure 1.

Series String of Parallel RC Pairs Equivalent Circuit. The clue to the use of the series string of parallel RC pairs equivalent circuit lies in the manner in which a transistor junction cools. A first inspection of a transistor junction cooling characteristic shows that it is an exponential decay, which may be duplicated with a paral-

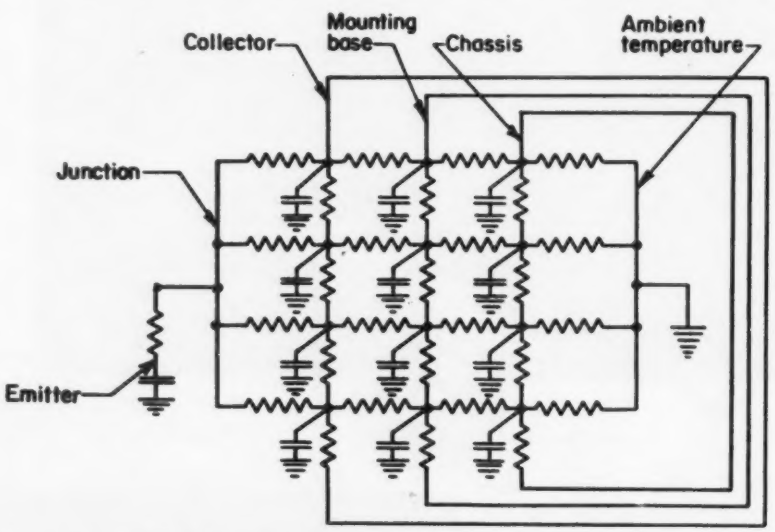

Fig 1 Transmission line thermal equivalent circuit.

This circuit is four parallel transmission lines, cross connected with resistors. If the transistor geometry is symmetrical, it is not necessary to use the parallel transmission lines. However, if the geometry is not symmetrical, the impedance of the various heat flow paths from the junction to ambient temperature is different and lateral heat flow will occur; thus the necessity of cross connecting resistors. From the circuit of Fig 1, it is obvious that we planned to divide the transistor into sections and lump the constants of these sections. This circuit is a simplified version of the circuit that would be necessary; more sections would be required closer to the transistor junction where the frequency response is higher. A 110 section transmission line thermal equivalent circuit was constructed and operated at the University of New Mexico[1].

lel combination of resistance and capacitance. A second closer look shows that the function is actually an exponential series, and thus a series string of parallel RC pairs. Mathematical proof of the use of this circuit was demonstrated by P. R. Strictland.[2] It is interesting to note that the original work upon which this proof is based was done back in the early 1930's.[3]

Data necessary for the computation of the circuit parameters are obtained experimentally from the transistor being evaluated. The first step is temperature calibration of the reverse-biased collector leakage current. This is done by placing the transistor in an oven, heating the transistor to the desired temperature, and measuring leakage current for various values of collector voltage. The results we obtained from this temperature calibration showed considerable variation of leakage current among transistors of the same 2N type number. The shapes of the characteristics were consistent, however. It is advisable to use five or six values of collector voltage because some individual transistors will exhibit I_{co} temperature characteristics which actually show a decrease in leakage current with an increase in temperature for specific values of collector voltage. This type of characteristic is useless for a temperature calibration.

The second step is to heat the transistor junction, remove the heating power, and measure the decay of I_{co} as the junction cools. The circuit used is shown in Figure 2.

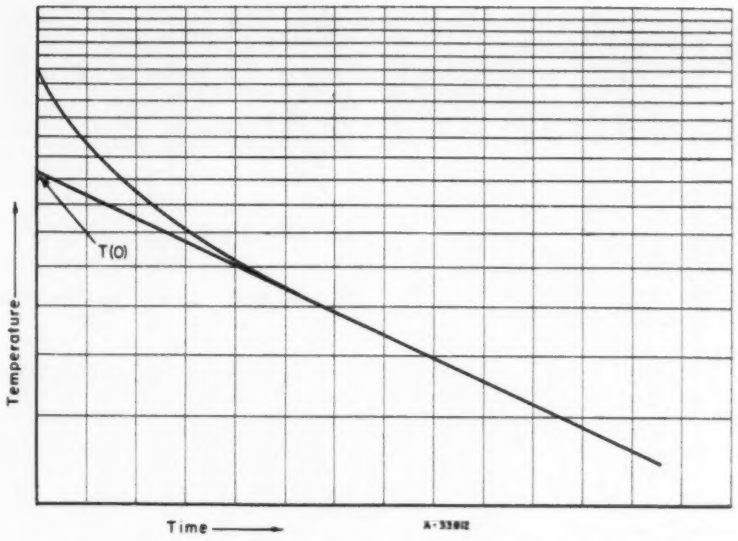

Fig 3 Transistor junction cooling curve 2N697 Network 1 calculations

I_{co} decay curves were translated into temperature decay curves. The value of the temperature of the heat sink, used during the experiment, was then subtracted from the decay curve and the results plotted on semilog graph paper were similar to the curve shown in Figure 3. Here, the horizontal axis is time and the vertical axis is temperature change in centigrade degrees. This curve is an infinite exponential series which converges very rapidly. Straight line extension of the flat portion of the curve represents the first term of the exponential series. The difference between the straight line and the curve represents the contribution of the remaining terms of the exponential series. The difference between the straight line and the curve was then plotted on semilog graph paper. This difference curve has the same general shape as the curve shown in Figure 3. Here, the straight line extension of the flat portion of the difference curve represents the second term of the exponential series. This process is repeated until the straight line and the curve are the same, within the desired limits of accuracy. So far this has occurred after 3 to 5 terms of the exponential series have been determined.

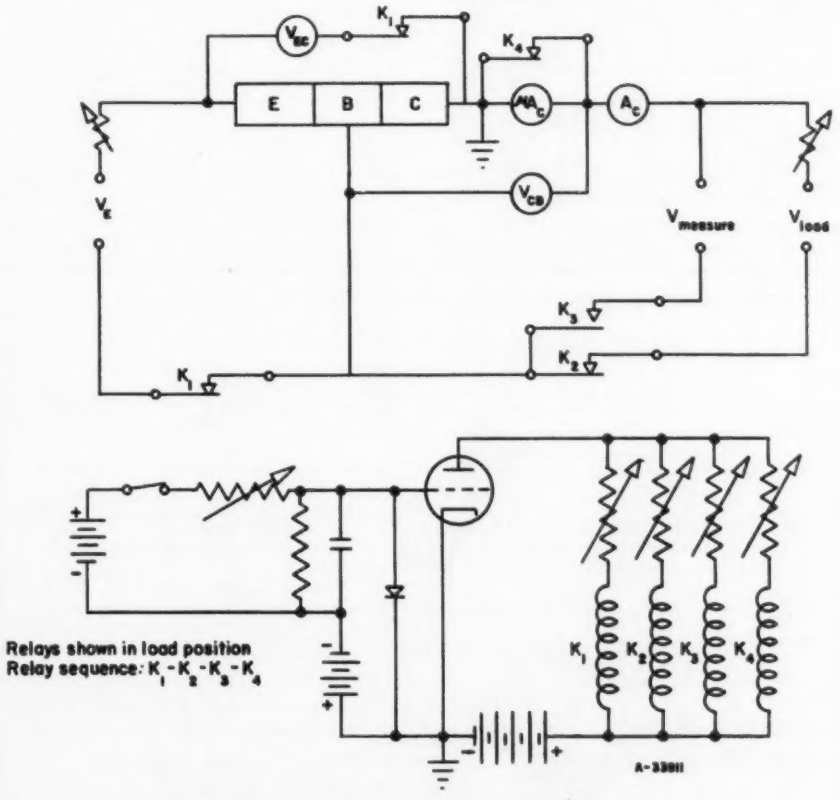

Fig 2 Loading and measuring circuit used to obtain the Junction Cooling Characteristics

For the sake of clarity, let us go through the calculation of the equivalent circuit constants for a 2N697 transistor. Figure 4-A is a plot of the junction cooling characteristic of the 2N697 transistor. From Figure 4-A we can see that the temperature across the first of the parallel *RC* pairs of our equivalent circuit was 98.7°C at time zero. The temperature had dropped to 93.0°C 100 milliseconds later. Temperature decay across the RC pair is described by the equation

$$T(n) = T(0)e^{-t/RC}$$

where

$T(n)$ = the temperature at time t, and
$T(0)$ = the temperature at time zero.

Thus, we have

$$93.0 = 98.7e^{-0.1/RC}$$

Solving for RC we get

$$RC = 1.689 \text{ seconds}$$

The value of R may be determined from the initial temperature across the *RC* pair which is actually the temperature at the end of the loading period, when the temperature across the *RC* pair had reached a steady state condition. Thus,

$R = T(0)/P$

where

P = power applied during loading, in watts (the 2N697 was loaded at 2 watts).

Substituting, we get

$R = 98.7/2 = 49.35°C/watt.$

Substituting the value of R in the time constant equation above, we get

$C = 3.42 \times 10^{-3}$ watt-second/°C.

The difference between the curve and the straight line of Figure 4-A is plotted in Figure 4-B. From Figure 4-B we get

$T(0) = 17.9°C,$
$T(n) = 4.01°C,$ and
$t = 0.05$ seconds.

From these values we may compute

$RC = 0.0334$ seconds,
$R = 8.95°C/watt,$ and
$C = 3.735 \times 10^{-3}$ watt-seconds/°C.

The difference between the straight line and the curve of Figure 4-B is next plotted as shown in Figure 4-C. From Figure 4-C we get

$T(0) = 41.0°C,$
$T(n) = 2.91°C,$
$t = 0.01$ seconds,
$RC = 0.00378$ seconds,
$R = 20.5°C/watt,$ and
$C = 1.844 \times 10^{-4}$ watt-seconds/°C.

The difference between the straight line and the curve of Figure 4-C was considered insignificant, so no further networks were computed. We shall go through the conversion of the above thermal units to electrical units after we have learned some of the limiting conditions imposed by the analog driving circuit.

Analog Circuit. The complete transistor thermal analog is shown in Figure 5. The analog network is shown on the right. Current through this network is equivalent to the heat flow in the transistor. Voltage that appears across the network is equivalent to the junction temperature rise above ambient temperature.

Current for the analog network is supplied by a 6AU6 vacuum tube. The 6AU6 is operated so that for a given voltage input current output is constant from almost zero to 90,000 ohms load impedance. Here, we have the first limiting factor for the conversion from thermal to electrical circuit constants: total resistance must be less than 90,000 ohms. The 6AU6 current source delivers a current made up of three parts. (1) P_c is a current equal to input power to the transistor. (2) P_{co} is a current equal to leakage power of the transistor. (3) P_q is the quiescent current delivered by the current source. Thus, voltage that appears across the analog network equals the junction temperature rise and a voltage caused by the quiescent current flow.

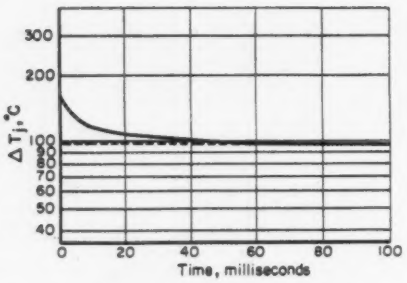

Fig 4A 2N697 Network 1 calculations

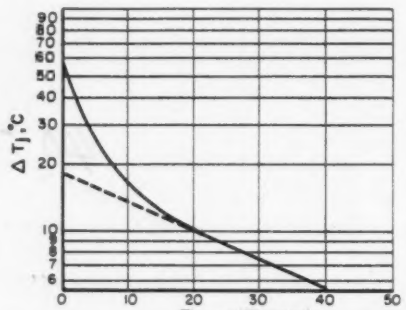

Fig 4B 2N697 Network 2 calculations

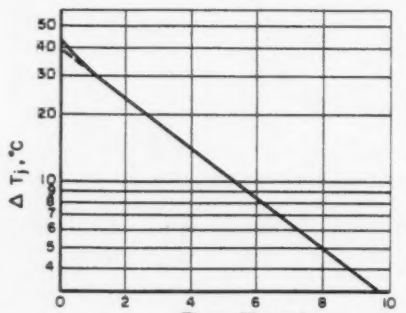

Fig 4C 2N697 Network 3 calculations

Leakage power of the transistor is produced by a feedback loop in the analog. The feedback loop is based on the assumption that the leakage current temperature characteristic is closely approximated by

$I_{co} = I'_{co}\, e^{kTj}$

where

I_{co} = leakage current at junction temperature Tj,
I'_{co} = leakage current at ambient temperature,
Tj = junction temperature in centigrade degrees above ambient temperature, and
k = a constant characteristic of the transistor.

Thus, the leakage power is

$P_{co} = I'_{co}\, V_c\, S\, e^{kTj}$

where

V_c = collector voltage, and
S = circuit stability factor.

This equation for leakage power may be rewritten

$P_{co} = \text{antilog}\,[\log I'_{co} + \log V_c + \log S + 0.4343kTj].$

A voltage equivalent to Tj is obtained from the high side of the analog network by balancing out the quiescent voltage with battery E_q. Quantity $1/k$ is equal to the degrees temperature rise of the transistor junction required to double I_{co} and this is usually of the order of about 11 degrees centigrade. Therefore, the quantity 0.4343k is obtained through use of an attenuator. The quantity 0.4343Tj is added to voltages equivalent to log I'_{co}, log V_c, and log S with an adding amplifier. The antilog of this sum is obtained through use of an arbitrary function generator. The output of the function generator is a voltage equivalent to P_{co}. This voltage is added to a voltage equivalent to input signal power, and the sum of the two voltages is used to drive the current souce.

Calibration is accomplished in the following manner. Let us use a 2N697 transistor as an example. The 2N697 transistor is a 2 watt silicon transistor with a maximum junction temperature

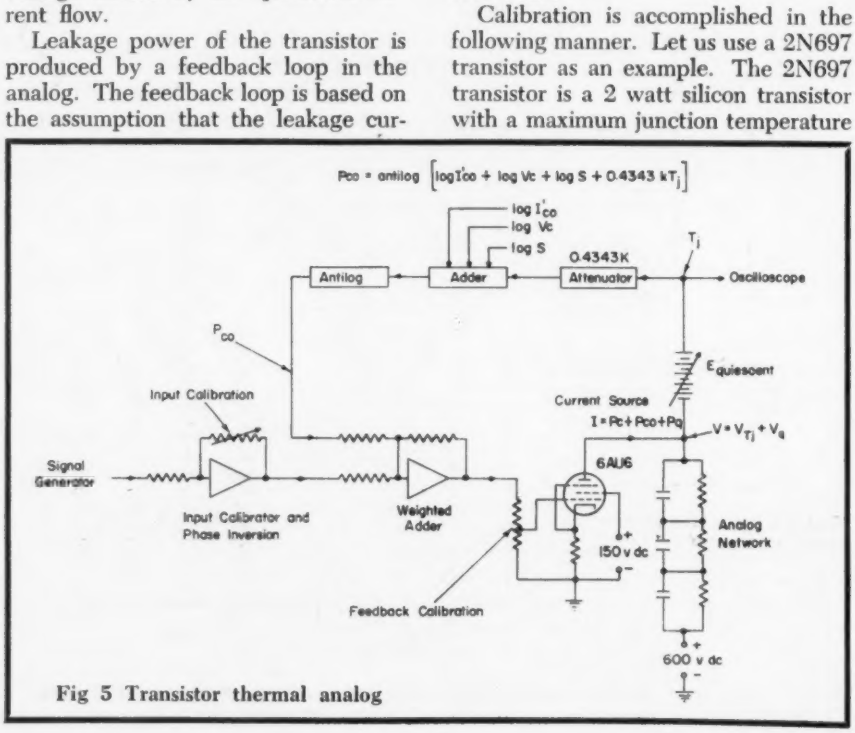

Fig 5 Transistor thermal analog

of 175 C.

The arbitrary function generator input and output are disconnected, and the attenuator is set for zero output. The log I'_{co} voltage source is set for the value of I_{co} at 170 C. Voltage output of the adder is measured and recorded. Log I_{co} voltage source is then adjusted to the minimum I_{co} value. For a 2N697 transistor, this is equal to a junction temperature of 90 C (about 1 microampere leakage current. A d-c voltage is then applied to the signal generator input which will produce a voltage across the analog network equivalent to an 80 C junction temperature rise (170-90 = 80). The attenuator is then adjusted so that the output equals the voltage recorded for I_{co} at a junction temperature of 170 C.

The arbitrary function generator (previously adjusted so that the output is the antilog of the input) is now connected into the circuit. Log V_c and log S voltage sources are then set for convenient values and the value of P_{co} is computed. With zero signal input, the feedback calibration attenuator is adjusted so that current flowing in the analog network is equivalent to the computed leakage power plus the quiescent current flow.

With the feedback loop disconnected, a d-c voltage is applied to the signal generator input. The input calibration potentiometer is then adjusted so that current flowing in the analog network is equivalent to the desired power equivalent for the voltage input. The analog is now calibrated and ready to operate.

Conversion From Thermal to Electrical Parameters. Conversion from thermal to electrical equivalent circuit parameters must be done considering the limitations of the circuit used to drive the analog network. We have already stated that the maximum resistance of the analog network must be less than 90,000 ohms. Maximum current the 6AU6 can deliver and still maintain linear operation is about 9 milliamperes while the quiescent current value is 1 milliampere. Thus the two major limiting conditions that must be considered when computing thermal-electrical equivalencies are a maximum resistance of 90,000 ohms and a current swing of 8 milliamperes. Now, let us go through a calculation.

Total thermal resistance of the 2N697 transistor is 78.80°C/watt (obtained by adding the thermal resistance from each of the three networks). The numbers come out a little better if we use some multiple of 418 (conversion from gram-calories per second to watts) for the number of ohms equivalent to 1°C/watt. Therefore, let us define

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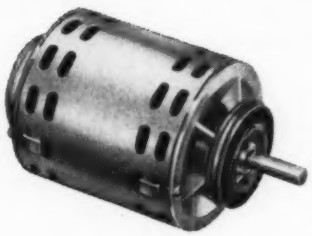

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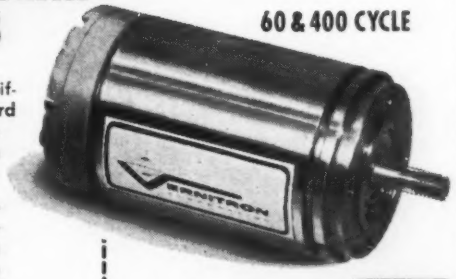

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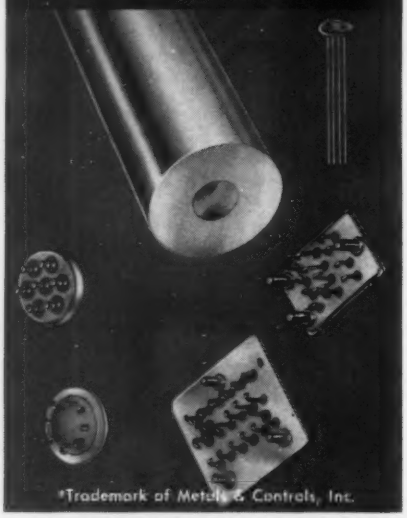

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836 ohms = 1°C/watt (1)

From this we get the total resistance of the three networks equal to 65,877 ohms, which is within our 90,000-ohm limitation.

By definition

1 g-cal/sec = 4.18 watts

From Equation (1) we get

836/4.18 ohms = 1°C/4.18 watts

or

200 ohms = 1°C/g-cal/sec. (2)

The 2N697 transistor has a power rating of 2 watts. Let us define the maximum power the transistor thermal analog must operate at as ten times the rating or 20 watts. Therefore, let us define

20 watts = 8.0 ma

or

1 watt = 0.4 ma.

By definition

1 watt = 0.239 g-cal/sec.

From this we get

1 watt = 0.4 ma = 0.239 g-cal/sec

or

1 g-cal/sec = 1.674 ma.

Ohm's Law applies to both the electrical and thermal circuit. Thus

$E = IR = (1.674 \times 10^{-3})(200) = .3348$ volts = 1°C

or

1 volt = 2.987°C

By definition

TABLE 1. 2N697 EQUIVALENT CIRCUIT CONSTANTS

Network	Resistance °C/W	Resistance K-Ohms	Capacitance W-Sec/°C	Capacitance Microfarads
1	49.35	41.26	0.03420	40.93
2	8.95	7.48	0.003732	4.46
3	20.50	17.14	0.0001844	0.221

1°C/w = 836 ohms
1°C = 0.3348 volts
1 w = 0.4 ma
1 w-sec/°C = 1196 μf

TABLE 2. 2N167 EQUIVALENT CIRCUIT CONSTANTS

Network	Resistance °C/W	Resistance K-Ohms	Capacitance W-Sec/°C	Capacitance Microfarads
1	458.0	47.86	0.002287	2.186
2	103.1	10.77	0.0001815	0.1735
3	48.0	5.02	0.0000927	0.08862
4	23.85	2.49	0.0000413	0.03948

1°C/w = 104.5 ohms
1°C = 1.288 volts
1 w = 12.31 ma
1 w-sec/°C = 956 μf

TABLE 3. 2N326 EQUIVALENT CIRCUIT CONSTANTS

Network	Resistance °C/W	Resistance K-Ohms	Capacitance W-Sec/°C	Capacitance Microfarads
1	2.855	39.74	0.1342	9.634
2	1.250	17.40	0.03680	2.642
3	0.493	6.86	0.02475	1.777

1°C/w = 13.92 K-ohms
1°C = 1.392 volts
1 w = 0.1 ma
1 w-sec/°C = 71.79 μf

TABLE 4. 2N335 EQUIVALENT CIRCUIT CONSTANTS

Network	Resistance °C/W	Resistance K-Ohms	Capacitance W-Sec/°C	Capacitance Microfarads
1	373	25.99	0.001394	19.91
2	117	8.15	0.00002620	0.3741
3	516	35.95	0.000001728	0.0247

1°C/w = 69.67 ohms
1°C = 0.3502 volts
1 w = 5.0 ma
1 w-sec/°C = 14280 μf

1.674×10^{-3} amperes = 1.674×10^{-3} coulombs/second

or

1.674×10^{-3} coulombs/second = 1 g-cal/second

Thus

1 coulomb = 597.4 g-cal

By definition

1 farad = 1 coulomb/volt

Thus

1 farad = 597.4 g-cal/2.987°C

or

1 farad = 200 g-cal/°C

By definition

1 watt-second = 0.239 g-cal

so

1 watt-second/°C = 1196 microfarads

Summarizing the above, we get

1°C/watt = 836 ohms,

1°C = 0.3348 volts,

1 watt = 0.4 milliamperes, and

1 w-sec/°C = 1196 microfarads.

These thermal-electrical equivalencies may now be used to compute the electrical equivalent circuit. Results of this computation are given in Table 1. It may be seen from Table 1 that

TABLE 5. 2N341 EQUIVALENT CIRCUIT CONSTANTS

Network	Resistance °C/W	Resistance K-Ohms	Capacitance W-Sec/°C	Capacitance Microfarads
1	54.2	22.66	0.03275	78.27
2	23.1	9.66	0.00195	4.661
3	72.2	30.18	0.0002244	0.5363

1°C/w = 418 ohms
1°C = 0.3361 volts
1 w = 0.8 ma
1 w-sec/°C = 2390 μf

TABLE 6. 2N384 EQUIVALENT CIRCUIT CONSTANTS

Network	Resistance °C/W	Resistance K-Ohms	Capacitance W-Sec/°C	Capacitance Microfarads
1	240.0	50.16	0.004440	2.122
2	34.30	7.17	0.0007040	0.3365
3	41.70	8.72	0.0000522	0.02495

1°C/w = 209.0 ohms
1°C = 1.395 volts
1 w = 6.667 ma
1 w-sec/°C = 4780 μf

TABLE 7. 2N502 EQUIVALENT CIRCUIT CONSTANTS

Network	Resistance °C/W	Resistance K-Ohms	Capacitance W-Sec/°C	Capacitance Microfarads
1	400.0	27.87	0.0001582	2.268
2	68.8	4.79	0.0006057	8.686
3	484.0	33.72	0.000007196	0.1032

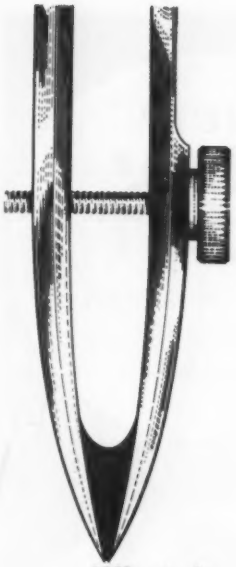
1°C/w = 69.97 ohms
1°C = 2.232 volts
1 w = 32.0 ma
1 w-sec/°C = 14340 μf

TABLE 8. 2N647 EQUIVALENT CIRCUIT CONSTANTS

Network	Resistance °C/W	Resistance K-Ohms	Capacitance W-Sec/°C	Capacitance Microfarads
1	62.0	25.92	0.02320	55.45
2	21.0	8.78	0.003175	7.588
3	14.0	5.85	0.0007520	1.797
4	2.62	1.10	0.0009050	2.163
5	31.8	13.29	0.0000204	0.04876

Analog operates 10 times faster than real time.

1°C/w = 418 ohms
1°C = 3.347 volts
1 w = 8.0 ma
1 w-sec/°C = 0.239 farads



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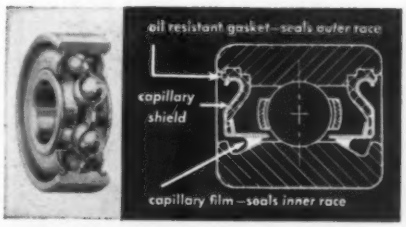

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NO INCREASE IN TORQUE

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the values of the capacitances are rather large. We may reduce these capacitance values by a factor of 10 by operating the thermal analog ten times faster than the transistor operates thermally.

Thermal Analog Operation

There are two ways of operating the transistor thermal analog: with and without the feedback loop. The analog may be operated without the feedback loop under conditions where the leakage power is very small with respect to the input power. This is generally true for silicon transistors. Major advantage of operation without the feedback loop is that the results are valid for all values of collector voltage, ambient operating temperature, and all the lower values of stability factor.

Results obtained from the analog for silicon transistors show various junction temperature rises plotted for peak input power as a function of duty cycle. No conditions of collector voltage, stability factor, or ambient temperature are defined. The results are valid for stability factors of less than 100 and for ambient temperature conditions lower than about 20 or 30 degrees less than the maximum junction operating temperatures.

Data for germanium transistors were taken using the feedback loop, for collector voltages of 100 and 50 per cent of rated, and ambient temperature conditions of 25 C and 65 C. The junction temperature rises given are 60 and 20 centigrade degrees which brings the junction temperature up to 85 C.

Thermal and electrical equivalent circuit constants for other transistor types may be found in Tables 2 through 8.

The analog was constructed so that the shunt and input resistors of the operational amplifiers were in plug-in units. This facilitates quick change of the weighing factors of the adder and the range of gain adjustment of the input calibration amplifier.

Chassis Operating Conditions

Thus far we have discussed transistor operation on an infinite heat sink of variable ambient temperature. Chassis conditions may be introduced by the inclusion of a tee network on the lower end of the analog network representing the transistor. They may be computed from the geometry of the transistor mounting configuration or measured from the actual chassis. The tee network need not have many sections because the frequency response is low.

Mounting of the transistors in air may be approximated by using the approximation that thermal resistance from the transistor to air is about 2 times the internal thermal resistance for low power transistors, 8 to 9 times the internal thermal resistance for medium power transistors, and 35 to 40 times the internal thermal resistance for power transistors. I cannot give proper credit for the above figures because I was unable to relocate the source article. Thermal capacitance for mounting in air is the thermal capacitance of the transistor itself. A good average for the specific heat of a transistor is approximately 0.12, and thus the thermal capacitance would be 0.12 times the weight of the transistor in grams.

We hope that other organizations will profit from our experience, and construct and use transistor thermal analogs for their specific purposes. Operation of the analog is greatly simplified if the actual transistor operating conditions are known when the problem is set up. Specialized wave shapes should present little difficulty. The results should be well worth the relatively small equipment cost. Increased reliability of circuit operation must certainly result.

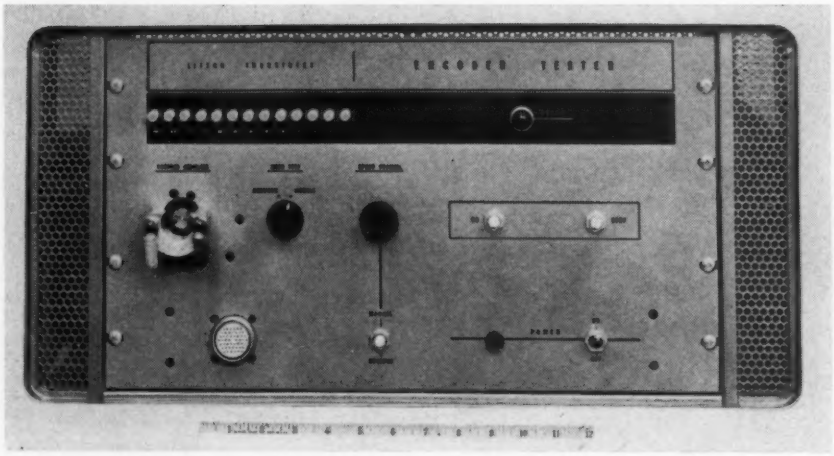
The design and development of the transistor thermal analog was carried out for the Bureau of Ships under Contract No. NObsr-77579. The title of this project was "Determination of Requirements for Overvoltage and Overload Protection of Transistors". The objective of the project was the determination of the design requirements for transistors. The development of the transistor thermal analog represents only a portion of the project. In addition to this development, experimental work was performed to verify the analog results. A survey was also made of transistorized equipment manufacturers to determine what methods they are using to protect the transistors of the equipment they manufacture.

References

1. Reese, J., and Grannemann, W. W., "An Electric Analog of Heat Flow in Power Transistors", University of New Mexico Engineering Experiment Station Technical Report EE-11 (June, 1958).
2. Strickland, P. R., "The Equivalent Circuit of a Transistor", IBM Journal of Research and Development, Vol. 3, No. 1 (January, 1959).
3. Guillemin, "Communication Networks", Volume II, page 210, Wiley, 1935.

SHAFT ENCODER TESTER

One Million Logic Operations In Less Than 3 Minutes



Using self-correlation techniques to evaluate brush-type, V-scan shaft encoders, Litton Systems' dynamic testing unit compares consecutive interrogations with each other, instead of with a second "standard" encoder. Testing is accomplished under dynamic driving conditions at variable shaft speeds up to 100 rpm with outputs interrogated periodically or on demand.

Logic circuitry requires that successive output words have changing value with an absolute difference no greater than one binary digit. If any other difference results, the comparison logic generates an error signal which stops the tester and energizes a light corresponding to the track on which the error occurred. If no error signal is generated the encoder is driven to its zero value output position, after which the logic circuit generates a signal to reverse the direction of shaft rotation. Cycling continues until the stop button or manual reverse button is pushed, or a readout error occurs. Instrument can test encoders in digital servos without the need of disassembly.

Autocorrelation rate of 6.25 kc provides such a high degree of exposure to the entire V-scan output that it may be regarded as almost continuous. At this rate, one million correlation/interrogations occur in less than three minutes of test time. A 13-bit word can be compared with all other words in 80 microseconds with a sampling time of 120 nanoseconds. Tester self-checks its error circuitry when a push-to-test button is depressed.

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Mr. Garrett Sanderson,
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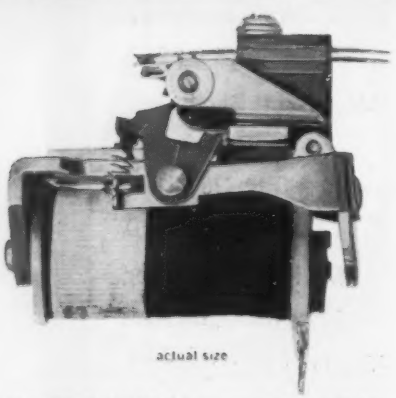
New York City, New York.
PLaza 3-6060.

Mr. Robert L. Baker,
360 No. Michigan Ave.,
Chicago, Ill. ANdover 3-3131

*For all you combination-and-permutation buffs, here's how the mathematics works out: The Series 1450 relay has up to 5 sets of SPSTNO contacts, each operated by a separate cam with a 12-tooth ratchet wheel. The cams are assembled on a splined shaft so that almost any desired orientation can be obtained. Consider an individual set of contacts. In any one complete 12-step rotation of the shaft, there are up to (2^{12}) different open-or-closed combinations for one set of contacts (including the equally unlikely 12-open- and 12-closed combinations). Thus, the total number of different programs theoretically possible for all five sets of con



actual size

The CDE Series 1450 program relay is suitable for sequential control of computer, military, machine tool, TV-remote or supervisory circuits. Available open, with dust cover, or hermetically sealed, with plug-in or solder terminal header.

with one Cornell-Dubilier relay: more programs

The number of different 12-step, 5-contact programs possible with the Cornell-Dubilier Series 145 relay is almost incredible—more than a billion-billion (1×10^{18}) different programs—more programs by far than the total number of U.S. pennies ever minted!* . . . But versatility is only part of the story.

Because switching programs in this small (4½-oz.) 5-pole relay are based on cam action, the exclusive design of the ratchet and cam assembly can be adapted to deliver any required sequence without cross wiring! The one-piece pawl and stop simultaneously engages, advances and stops the ratchet, resulting in a positive-acting impulse-latching logic that stays without holding power!

Yet, surprisingly, the CDE Series 1450 relay costs 50-95% less than others that might only begin to meet your requirements. And you'll be interested in our exceptional delivery schedules — just 4 to 6 weeks on most designs.

Here are some additional performance details:

Fast! 10 millisecs. max. for a .055 watt-sec. pulse. Coil ratings are 6 to 220 VDC or 60-cycle AC. Palladium, silver or gold contacts are available with ratings up to 7.5 amps, 115 VAC.

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tacts is $(2^{12})^5$ or $(2^{60}) = 1,152,921,504,606,846,976$. Or, consider one setting of the 5 sets of contacts. In any one cam shaft position, the 5 sets of contact can be arranged in up to (2^5) different open-or-closed combinations. Thus the total number of combinations for all 12 different cam shaft positions is $(2^5)^{12}$ o (2^{60}), the same result as above. The Director of the U.S. Mint reports there were 1,990,112,655 one-cent pieces issued for circulation during fiscal year 196C Extending this approximate 2-billion pennies/annum figure back over this country's almost 200-year history, the mathematical validity is quickly apparent

than all the U.S. pennies ever minted!

Reliable! Designed and built for over 10 million operations! Substantially immune to vibration and shock, the standard Series 1450 is designed for operation up to 85° C. What's more, the sintered nylon ratchet, stop and cam shaft switching system needs no lubrication over life.

Space-Saving! 50 to 75% smaller than similar devices; weighs only 4½-oz.

The series 1450 relay is only one of many cam-actuated, impulse-type programming and bi-stable relays engineered and built by Cornell-Dubilier in its superbly-equipped plant in Fuquay Springs, N. C. CDE also produces the following complete lines of relays for commercial, industrial and military applications: high-reliability telephone-type relays, miniature semi-sensitive general-purpose relays, intermediate multi-pole general-purpose relays, miniature heavy-duty power contactors, deliberately desensitized differential relays for electromechanical discrimination, solenoids and hundreds of special types.

If you are in any way involved in specifying relays, contact your CDE representative or our Marketing Department. Convince yourself that in relays, as in hundreds of other electronic component and system categories, Cornell-Dubilier Can Do!

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SERVOMOTORS Part III

Performance Characteristics

In Oct, 1958 Electromechanical Design presented its first Components Digest, Part I, on servomotors. In the three years since the appearance of this comprehensive presentation, the principal advances in servomotors have been in the area of miniaturization and high temperature performance. Miniature motors,

SUMMARY OF PERFORMANCE

		IMC MAGNETICS										
1.	Company (See Buyer's Guide)											
2.	Model No.	BT707-5	BC904-2	BT904	BT905-3	BT1007	BT1407-1	BT1708-6	BT505	BT705-1	BT707-2	BT10
3.	Weight (oz.); Approx. Length (inches)	1.7, 1.22	1.6, 0.766	1.6, 0.766	2.3, 0.26	4.3, 1.37	7, 1.633	14, 2.23	0.68, 1.0	1.6, 1.06	1.9, 1.46	4.2,
4.	Size	8	10	10	10	11	15	18	5	8	8	11
5.	Frequency (cps)	400	400	400	400	400	60	60	400	400	400	400
6.	Rotor Inertia (gm-cm²)	0.89	0.47	0.47	0.66	1.07	3.3	4.0	0.15	0.65	1.0	1.07
7.	Stall Torque (in-oz)	0.26	0.18	0.31	0.50	0.63	1.5	4.2	0.09	0.33	0.35	0.63
8.	Internal Damping (dyne-cm-sec)	28.7	12.7	33.6	55	66.9	330	888	6.2	36.1	38.5	66.9
9.	No Load Speed (rpm)	6200	9500	6200	6200	6200	3200	3200	9500	6200	6200	6200
10.	Time Constant (sec.)	0.031	0.037	0.014	0.012	0.016	0.01	0.0045	0.024	0.018	0.026	0.016
11.	Theoretical Acceleration at Stall (rad/sec²)	20600	27100	46700	53500	41500	32000	74400	42500	35500	3200	4150
12.	Effective Resistance (ohms) Control Phase	390	2166	2470	757	457	2080	168	383	593	220	3800
13.	Voltage Fixed Phase volts	115	115	26	115	115	115	115	26	26	26	115
	Voltage Control Phase volts	33	57	80	50	40/20	115/57	40/20	26/13	40	26	115
14.	Power Fixed Phase watts	3.2	1.5	3.2	4.1	3.5	6.4	9.5	1.75	2.7	3.06	3.5
	Power Control Phase watts	2.8	1.5	2.6	3.3	3.5	6.4	9.5	1.75	2.7	3.06	3.5
15.	Power Factor (Control Phase)	0.63	0.6	0.63	0.55	0.58	0.88	0.72	0.85	0.69	0.77	0.58
16.	Operating Temp. Range (°C)	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +12

		BASLER ELECTRONICS			
1.	Company (See Buyer's Guide)				
2.	Model No.	MARK 14 MOD 2	MARK 14 MOD 3	MARK 7 MOD 1	MARK 7 MOD 2
3.	Weight (oz.); Approx. Length (inches)	3.5, 1.7	3.5, 1.7	8.0, 1.6	8.0, 1.6
4.	Size	11	11	15	15
5.	Frequency (cps)	400	400	400	400
6.	Rotor Inertia (gm-cm²)	1.07	1.07	3.2	3.2
7.	Stall Torque (in-oz)	0.6	0.6	1.45	1.45
8.	Internal Damping (dyne-cm-sec)	64.2	64.2	202	202
9.	No Load Speed (rpm)	6300	6300	4800	4800
10.	Time Constant (sec.)	0.0166	0.0166	0.0158	0.0158
11.	Theoretical Acceleration at Stall (rad/sec²)	39596	39596	31990	31990
12.	Effective Resistance (ohms) Control Phase	3700	9200	1900	7700
13.	Voltage Fixed Phase volts	115	115	115	115
	Voltage Control Phase volts	115/57.5	180/90	115/57.5	230/115
14.	Power Fixed Phase watts	3.5	3.5	6.8	6.8
	Power Control Phase watts	3.5	3.5	6.8	6.8
15.	Power Factor (Control Phase)	—	—	—	—
16.	Operating Temp. Range (°C)	+150	+150	+150	+150

		DAYSTROM TRANSICOIL				
1.						
2.	5M4	8M4	8MF4	11MA2	11M
3.	0.7, 31/32	1.5, 61/64	2.6, 1.82	4.5, 1.5	9, 2
4.	5	8	8	11	11
5.	400	400	400	60	400
6.	0.19	0.19	0.7	1.2	3.2
7.	0.10	0.20	0.2	1.0	0.35
8.			120		140
9.	10000	10000	10000	59000	950
10.	0.028	0.014	0.0058	0.0057	0.00
11.	37200	74500	20000	3200	770
12.	398	640	640	370	370
13.	26	26	26	115	115
	26	33	33	36	36
14.	1.7	1.7	1.7	3.5	3.5
	1.7	1.7	1.7	3.5	3.5
15.	0.654	0.669	0.644	0.845	0.69
16.	−55 +125	−55 +125	−55 +125	−55 +125	−55 +12

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CEDAR ENGRG. DIV., CONTROL DATA CORP.
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CLIFTON PRECISION PRODUCTS CO.
Marple at Broadway, Clifton Heights, Pa.
DAYSTROM INC., TRANSICOIL DIV., Worcester, Pa.
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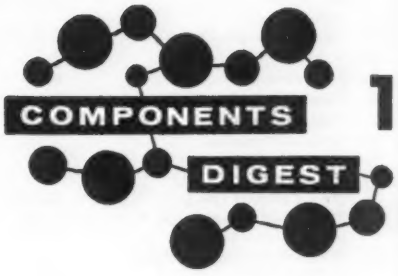

motor-generators, and gearheads are becoming increasingly available in size 5 (½ inch diameter). Temperature ratings are up to 200°C on new models.

In this presentation, we have again queried manufacturers about their latest models and present below a tabulation of performance characteristics as they were submitted.

CHARACTERISTICS OF SERVOMOTORS

	BT1708-2	BT1708-8	BT1007J	BT1007-3
	12, 1.89	12, 1.89	6.5, 2.18	4.2, 1.32
	18	18	11	11
	400	400	400	1600
	4.0	4.0	1.0	1.07
	2.5	2.8	0.63	0.1
	114	190	100	3.1
	9000	9800	6200	22,000
	0.035	0.021	0.01	0.35
	36500	49500	44490	6400
	385	808	457	121
	115	115	115	26
	57.5	115/57.5	40/20	20/10
	8.6	16.5	3.5	3.6
	8.6	16.5	3.5	3.3
	0.75	0.62	0.55	0.77
	−55	−55	−55	−55
	+125	+125	+125	+125

	GM LABORATORIES					
	556A	5421A	5437A	5245A	5073A	53104A
	2.3, 1.2	3.5, 1.8	4.2, 1.7	8.0, 1.6	11, 1.8	12, 2
	10	11	11	15	18	18
	400	400	400	400	60	400
	0.5	1.07	1.07	3.2	10.5	4.0
	0.26	0.60	0.60	1.45	2.5	2.25
	17.5	60.7	60.7	202	1052	317
	10000	6300	6300	4800	1600	4800
	0.0285	0.0176	0.0176	0.0158	0.0099	0.0126
	36722	39547	39547	31990	16807	39547
	205	3778	231	1945	1653	1453
	26	115	115	115	115	115
	26	115	30	115	115	115
	3.3	3.5	3.9	6.8	8	9.1
	3.3	3.5	3.9	6.8	8	9.1
	—	—	—	—	—	—
	−54	−54	−54	−54	−54	−54
	+125	+125	+125	+125	+125	+125

	SCHAEVITZ	
	DM - 10	DM
	1.75, 1	26, 3.6
	10	23
	400	60
	0.44	——
	0.35	14
	59	——
	9000	3490
	0.014	——
	——	——
	2500	4200
	115	115
	75	150
	3	14.7
	0.65	0.70
	0	0
	+100	+100

	11MAF2	15MA2	15MF8	18MAF2
	7.8, 2.31	7.5, 1.7	12, 2.9	18, 3.4
	11	15	15	18
	60	60	400	60
	3.0	3.2	5.4	5.8
	4.0	2.0	1.45	4.0
	400		1400	1400
	3200	3200	5000	3200
	0.0028	0.0076	0.0038	0.0041
	45200	44100	19000	48750
	370	212	212	164
	115	115	115	115
	36	36	36	36
	6.5	6.1	6.1	9
	6.5	6.1	6.1	9
	0.845	0.792	0.506	0.817
	−55	−55	−55	−55
	+125	+125	+125	+125

	TRANSCO PRODUCTS			
	12-A	12-B	15-A	15-B
	4.2, —	4.2, —	5.6, —	5.6, —
	12	12	15	15
	400	400	400	400
	1.0	0 6	1.8	0.9
	0.8	0.3	1.0	0.45
	60	25	85	31
	6500	6200	7000	6300
	0.015	0.010	0.013	0.009
	40000	62000	42000	65000
	450	450	510	510
	115	115	115	115
	115	115	115	115
	4.0	4.0	4.6	4.6
	4.0	4.0	4.6	4.6
	—	—	—	—
	−50	−50	−50	−50
	+125	+125	+125	+125

	FORD EL.
	18-AII
	12, 2.25
	18
	60
	9.5
	5
	——
	3400
	——
	——
	——
	115
	26
	25
	12
	——
	−55
	+75

	PHOTOCIRCUITS CORPORATION			
	368	488	668	1028
	48	104	208	912
	2.25	2.4	2.53	4.72
	12	42.5	140	1000
	DC	DC	DC	DC
	0.694	3.194	16.060	114.975
	60	220	1150	8500
	Available in several ranges			
	5000	4800	2800	1700
	0.034	0.040	0.024	0.020
	Varies with operating voltage (pulse technique)			
	0.63	0.971	0.52	0.464
	DC	DC	DC	DC
	DC	DC	DC	DC
	DC	DC	DC	DC
	−54	−54	−54	−54
	+50	+50	+50	+50

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1 Main St., Racine, Wisc.
PHOTOCIRCUITS CORP., 31 Sea Cliff Ave., Glen Cove, N. Y.
ROTATING COMPONENTS, INC.
267 Green St., Brooklyn, N. Y.
SCHAEVITZ ENGRNG.
U.S. Route 130 & Schaevitz Blvd., Pennsauken, N. J.
SERVOMECHANISMS, INC., MECHATROL DIV.
1200 Prospect Ave., Westbury, L.I., N. Y.
TRANSCO PRODUCTS, 12210 Nebraska Ave., L. A., Calif.
WESTERN GEAR CORP., ELECTRO PRODS. DIV.
132 W. Colorado St., Pasadena, Calif.
WRIGHT MACHINERY CO., DIV. OF SPERRY RAND CORP.
Durham, N. C.

	WRIGHT MACHINERY CO.									
1. Company (See Buyer's Guide)										
2. Model No.	20D633-2	20D633-4	20D627-2	20D624-4	20D619-2	20D591-4	20D602-4	20D611-2	20D647-4	20D595-4
3. Weight (oz); Approx. Length (inches)	1.25, 0.831	1.25, 0.831	1.55, 1.052	1.55, 1.052	2.25, 1.263	7.3, 1.518	4.5, 1.39	12.2, 1.900	12.2, 1.716	1.25, 0.831
4. Size	8	8	8L	8L	9	15	11	18	18	8
5. Frequency (cps)	400	400	400	400	400	400	400	400	400	400
6. Rotor Inertia (gm-cm²)	0.147	0.147	0.248	0.195	0.833	3.3	0.980	4.0	4.0	0.12
7. Stall Torque (in-oz)	0.22	0.22	0.33	0.35	0.25	1.3	0.60	2.3	2.7	0.20
8. Internal Damping (dyne-cm-sec)	24.0	24 0	35.9	24.1	17.2	183	65.4	295	1.86	13.8
9. No Load Speed (rpm)	6200	6200	6200	9800	9800	4800	6200	4800	9800	9800
10. Time Constant (sec.)	0.00613	0.00613	0.0069	0.0081	0.0484	0.0180	0.015	0.0136	0.0215	0.00872
11. Theoretical Accelergtion at Stall (rad/sec²)	106000	106000	98000	127000	21100	4800	43300	31000	47800	118000
12. Effective Resistance (ohms) Control Phase	273	518	3790	398	280	206	364	1460	80	570
13. Voltage Fixed Phase volts	26	26	115	115	26	115	115	115	115	26
Voltage Control Phase volts	26	36	115/57.5	36	26	36	36	115/57.5	36	36
14. Power Fixed Phase watts	2.5	2.5	3.5	3.2	2.3	6.2	3.5	9.1	16 2	2.2
Power Control Phase watts	2.5	2.5	3.5	3.2	2.3	6.2	3.5	9.1	16 2	2.2
15. Power Factor (Control Phase)	0.778	0.778	0.775	0.620	0.722	0.482	0.575	0.438	0.666	0.682
16. Operating Temp. Range (°C)	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125

	THOMAS A. EDISON INC., INSTRU. DIV.									
1. Company (See Buyer's Guide)										
2. Model No.	M8003-12	M10001-11	M10002-12	M11001-11	M11001-19	M15002-15	M15002-17	M18002-11	M18002-13	M18002-16
3. Weight (oz.); Approx. Length (inches)	1.5, 0.95	1.5, 0.91	1.45, 0.76	4.5, 1.70	4.5, 1.70	7.5, 1.62	7.5, 1.62	12.2, 2.0	12.2, 2.0	12.2, 2.0
4. Size	8	10	10	11	11	15	15	18	18	18
5. Frequency (cps)	400	400	400	400	60	400	60	400	60	60
6. Rotor Inertia (gm-cm²)	0.85	0.48	0.46	1.1	1.1	3.3	3.3	4.0	4.0	4.0
7. Stall Torque (in-oz)	0.20	0.28	0.30	0.60	0.60	1.45	1.45	2.35	3.3	3.3
8. Internal Damping (dyne-cm-sec)	—	—	—	—	—	—	—	—	—	—
9. No Load Speed (rpm)	6200	9000	6500	6200	3100	4800	3100	4800	3100	3100
10. Time Constant (sec.)	0.0416	0.025	0.015	0.017	0.008	0.016	0.010	0.012	0.0055	0.0055
11. Theoretical Acceleration at Stall (rad/sec²)	16800	42700	49000	41500	39800	32000	32000	42000	65000	65000
12. Effective Resistance (ohms) Control Phase	357	1785	250	3800	865	246	1900	1460	1390	168
13. Voltage Fixed Phase volts	26	72	26	115	55	115	115	115	115	115
Voltage Control Phase volts	26	72	26	115	55	40	115	115	115	40
14. Power Fixed Phase watts	2.4	2.8	2.7	3.5	3.5	6.5	6.5	9.5	9.5	9.5
Power Control Phase watts	2.4	2.8	2.7	3.5	3.5	6.5	6.5	9.5	9.5	9.5
15. Power Factor (Control Phase)	0.76	0.73	0.63	0.58	0.80	0.48	0.73	0.43	0.77	0.77
16. Operating Temp. Range (°C)	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125

	BECKMAN INSTR., HELIPOT DIV.							
1. Company (See Buyer's Guide)								
2. Model No.	9005-1502-0	9008-1501-0	9008-1502-0	9011-1501-0	9011-1503-0	9015-1502-0	9018-1501-0	9018-1503-0
3. Weight (oz.); Approx. Length (inches)	0.6, —	1.1, —	1.6, —	4, —	5, —	8, —	15, —	15, —
4. Size	5	8	8	11	11	15	18	18
5. Frequency (cps)	400	400	400	400	60	400	400	60
6. Rotor Inertia (gm-cm²)	0.14	0.18	0.27	1.07	1.07	1.07	4.0	4.0
7. Stall Torque (in-oz)	0.1	0.22	0.33	0.6	0.65	1.45	2.4	4.0
8. Internal Damping (dyne-cm-sec)	6.7	25.0	37.0	67.5	137	164	325	900
9. No Load Speed (rpm)	10000	6000	6000	6000	3200	6000	5000	3000
10. Time Constant (sec.)	0.021	0.0075	0.0075	0.016	0.008	0.0065	0.012	0.0045
11. Theoretical Acceleration at Stall (rad/sec²)	50000	86500	86500	41500	43000	100000	42500	70000
12. Effective Resistance (ohms) Control Phase	544	403	311	410	533	186	9375	8711
13. Voltage Fixed Phase volts	26	26	115	115	115	115	115	115
Voltage Control Phase volts	33	33	33	40	40	40	300	280
14. Power Fixed Phase watts	2.0	3.1	3.5	3.9	3.0	8.5	9.2	9.0
Power Control Phase watts	2.0	2.7	3.5	3.9	3.0	8.5	9.6	9.0
15. Power Factor (Control Phase)	0.87	0.63	0.61	0.56	0.76	0.5	0.43	0.64
16. Operating Temp. Range (°C)	−55 +130	−55 +130	−55 +130	−55 +130	−55 +130	−55 +130	−55 +130	−55 +130

	M-H REG. CO., BROWN INSTR. DIV.							
1. Company (See Buyer's Guide)								
2. Model No.	362479-1	362479-2	362479-3	362479-4	362479-5	362480-1	362480-2	702199
3. Weight (oz.); Approx. Length (inches)	29, 2.75	29, 2.75	29, 2.75	29, 2.75	29, 2.75	29, 2.75	29, 2.75	29, 2.75
4. Size	—	—	—	—	—	—	—	—
5. Frequency (cps)	60	60	60	25	25	60	25	60
6. Rotor Inertia (gm-cm²)	27	27	27	27	27	27	27	27
7. Stall Torque (in-oz)	28	68	145	46	23	13.9	9.7	45
8. Internal Damping (dyne-cm-sec)	—	—	—	—	—	—	—	—
9. No Load Speed (rpm)	152	50	26	25	49	345	139	103
10. Time Constant (sec.)	—	—	—	—	—	—	—	—
11. Theoretical Acceleration at Stall (rad/sec²)	—	—	—	—	—	—	—	—
12. Effective Resistance (ohms) Control Phase	26450	26450	26450	13225	13225	26450	13225	26450
13. Voltage Fixed Phase volts	115	115	115	115	115	115	115	115
Voltage Control Phase volts	115	115	115	115	115	115	115	115
14. Power Fixed Phase watts	11.0	11.0	11.0	4.0	4.0	11.0	4.0	11.0
Power Control Phase watts	0.5	0.5	0.5	1.0	1.0	0.5	1.0	0.5
15. Power Factor (Control Phase)	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
16. Operating Temp. Range (°C)	−18 +66	−18 +66	−18 +66	−18 +66	−18 +66	−18 +66	−18 +66	−18 +66

	HOLTZER-CABOT DI	
1.		
2.	2405	2407
3.	24, 2.3	28, 2.4
4.	41/16 dia.	41/16
5.	60	60
6.	12	16
7.	1.8	3.3
8.	800	1350
9.	1500	1600
10.	0.014	0.012
11.	11000	15000
12.	8800	10000
13.	115	115
	120	200
14.	7.5	8.8
	2.0	4.5
15.	0.57	0.5
16.	0 +50	0 +50

	11S1-3	11S1-16
1.		
2.		
3.	4.5, 27/64	4.5, 27
4.	11	11
5.	400	400
6.	1.07	1.07
7.	0.6	0.6
8.		
9.	6200	6200
10.	0.017	0.017
11.	41500	41500
12.	457	193
13.	115	115
	40/20	26
14.	3.5/3.5	3.5/3.5
15.	0.55	0.55
16.	−55 +125	−55 +125

CHARACTERISTICS OF SERVOMOTORS, *con't.*

	BOWMAR INSTRUMENT							
1.								
2.	M80-000	M80-004	M80-005	M100-500	M110-501	M100-504	M105-500	M110-500
3.	1.7, 1.20	1.7, 1.20	1.7, 1.20	1.8, 0.961	1.8, 1.012	1.8, 0.959	4.5, 1.453	4.5, 1.453
4.	8	8	8	10	10	10	11	11
5.	400	400	400	400	400	400	400	400
6.	1.07	1.07	1.07	0.46	0.46	0.46	1.07	1.07
7.	0.35	0.35	0.40	0.30	0.28	0.24	1.00	1.00
8.	36.3	36.3	41.5	31.1	32.6	40 5	21.7	21.7
9.	6500	6500	6500	6500	5800	4000	6200	6200
10.	0.030	0.030	0.026	0.015	0.015	0.016	0.0098	0.0098
11.	23000	23000	23000	49000	49000	36800	66000	66000
12.	218	218	218	250	4300	170	2170	2170
13.	26 26	26 36	26 26	26 26	115 36	26 35	115 115	115 230
14.	3.1 3.1	3.1 3.1	3.1 3.1	2.6 2.6	3.07 2.53	4.0 2.5	6.1 6.1	6.8 6.8
15.	0.72	0.73	0.72	0.63	0.625	0.53	0.58	0.58
16.	−54 +125	−54 +125	−54 +125	−54 +125	−54 +125	−55 +125	−55 +125	−55 +125

	KEARFOTT DIV., GENERAL PRECISION										
J126-02	R123-2	R125-6	R118-1	P121-02	R119-24	R110-2-22	423295-1	R110-5-25	T175-001	R112-5	R160-2
	1.6, 1.24	1.0, -	1.45, 0.97	1 7, —	4.5, 1.74	7.3, 1.56	7.3, —	7.3, 1.56	12.2, 1.89	12.2, —	12.2, —
5	8	8	10	10	11	15	15	15	18	18	18
400	400	400	400	400	400	400	400	400	400	400	60
0.175	1.07	0.46	0.46	0.46	1.07	3.3	3.3	3.3	4	4	4
0.10	0.33	0.10	0.30	0.28	0.60	1.53	1	1.53	2.4	2.8	3.48
	35.8	19.2	57.5	18.9	64.5	195	135	195	336	194	742
9800	6200	3500	6500	10000	6200	5300	5000	5300	4800	9800	3400
	0.03	0.024	0.0153	0.0685	0.017	0.017	0.017	0.017	0.0119	0.020	0.0058
	21780	15353	46058	42986	39596	32739	21397	32739	42372	49434	61439
	199	230	250	5280	950	2200	2450	266	1460	100	1590
26 26	26 26	18 18	26 26	115 115	115 57.5	115 115/57.5	115 115/57.5	115 40/20	115 115/57.5	115 40/20	115 115/58
1.7 1.7	3.4 3.4	1.5 1.5	2.6 2.6	2.5 2.5	3.5 3.5	6.2 6.2	5.4 5.4	6.2 6.2	9.3 9.3	16 16	9.3 9.3
	0.72	0.87	0.63	0.72	0.575	0.49	0.49	0.49	0.43	0.61	0.71
−55 +125	−54 +125	−54 +125	−54 +125	−54 +125	−54 +125	−54 +125	−54 +150	−54 +125	−54 +200	−54 +125	−54 +125

	SERVOMECHANISMS, INC., MECHATROL DIVISION						
11S1-30	10S2-24	10S2-30	10S3-14	5S2-1	5S2-2	
4.5, 27/64	1.45, 27/32	1.45, 27/32	4, 1.3	.85, 0.999	.85,0.999	
11	10	10	10	5	5	
400	400	400	400	400	400	
1.07	0.46	0.46	1.07	0.18	0.18	
0.45	0.3	0.27	0.6	0.10	0.10	
8500	6200	10000	6200	10000	10000	
0.03	0.0136	0.024	0.017	0.027	0.027	
31000	49000	46000	41500	42000	42000	
457	615	5290	193	322	190	
115 40/20	115 40/20	115 115	26 26/13	26 26	20 20	
3.5/3.5	2.8/2 6	2.5/2.5	3.5/3.5	2.1/2.1	2.2/2.1	
0.80	0.59	0.72	0.55	0.87	0.87	
−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	

	WESTERN GEAR			
1.				
2.	80501-990001	80501-990002	80501-990003	80502-990001
3.	3.5, 1.4	3.5, 1.4	3.5, 1.4	4.2, 1.6
4.	1" dia.	1" dia.	1" dia.	1" dia.
5.	400	400	400	400
6.	1.0	1.0	1.0	1.2
7.	0.62	0.4	0.62	0.41
8.	67.4	40.4	67.4	45.9
9.	6200	6200	6200	6000
10.	0.0148	0.0247	0.0148	0.0261
11.	43700	28300	43700	24000
12.	3075	3673	125	3778
13.	115 115	115 115	26 26	115 115
14.	4.3 4.3	3.6 3.6	5.4 5.4	3.5 3.5
15.	0.59	0 69	0.67	0.69
16.	−55 +125	−55 +125	−55 +125	−55 +125

	TIONAL PNEUMATIC	
1.		
2.	2414	
3.	42, 3.1	
4.	41/16 dia.	
5.	60	
6.	36	
7.	5.0	
8.	2050	
9.	1600	
10.	0.018	
11.	10000	
12.	8700	
13.	115 255	
14.	10.5 5.5	
15.	0.6	
16.	0 +50	

	CLIFTON PRECISION PRODUCTS								
1.									
2.	ACH-8-A-1	AMH-8-A-1	ALH 8-A-4	ACH-10-A-1	ALH-10-A-1	ALH-10-A-3	ALH-10-A-4	ACH-11-AS-3	ACH-11-AS-4
3.	0.95, 0.83	1.37, 1	1.58, 1.17	1.4, 0.97	2.3, 1.17	2.3, 1.17	2.3, 1.17	3.3, 1.27	3.3 1.27
4.	8	8	8	10	10	10	10	11	11
5.	400	400	400	400	40	100	400	400	400
6.	0.38	0.81	1.0	0.38	1.0	1.0	1.0	1.0	1.0
7.	0.16	0.27	0.30	0.30	0.60	0.18	0.44	0.60	0.60
8.	15	29	30	27	62	76	52	62	62
9.	6200	6200	6200	6500	6500	1600	6500	6500	6500
10.	0.022	0.028	0.032	0.014	0.016	0.013	0.019	0.016	0.016
11.	28000	23500	21000	55700	50000	12700	35000	42400	42400
12.	356	397	703	270	5280	1066	612	3390	457
13.	26 26	26 26	26 35	26 26	115 115	13 40	115 35	115 115	115 40
14.	1.9 1.9	1.7 1.7	1.6 1.6	2.5 2.5	2.5 2.5	2.4 1.5	2.5 2.0	3.9 3.9	3.9 3.5
15.	0.696	0.523	0.538	0.519	0.302	0.536	0.635	0.565	0.5
16.	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125

	JOHN OSTER MFG. CO.										
1. Company (See Buyer's Guide)											
2. Model No.	5002-03	5004-01	5051-12	5051-19	5051-20	5051-21	5052-01	5060-01	5201-01	5203-03	5205-0
3. Weight (oz.) Approx. Length (inches)	1.6, —	1.2, —	1.6, 1.156	2.1, 0.975	1.6, 1.156	2.1, 0.975	1.7, 0.871	1.2, 0.5	13.5, 2.03	13.5, 2.03	13.5,
4. Size	8	8	10	10	10	10	10	10	18	18	18
5. Frequency (cps)	400	400	400	400	400	400	400	400	400	400	60
6. Rotor Inertia (gm-cm²)	1.07	0.41	0.46	0.55	0.55	0.46	0.46	0.18	4.0	4.0	4.0
7. Stall Torque (in-oz)	0.35	0.18	0.20	0.13	0.13	0.27	0.32	0.10	2.35	2.80	3.50
8. Internal Damping (dyne-cm-sec)	—	—	—	—	—	—	—	—	—	—	—
9. No Load Speed (rpm)	7400	6000	10000	10000	10000	10000	7200	6000	5300	10500	3400
10. Time Constant (sec.)	0.0335	0.0232	0.0340	0.0625	0.0625	0.0253	0.0153	0.016	0.01335	0.0222	0.005
11. Theoretical Acceleration at Stall (rad/sec²)	—	—	—	—	—	—	—	—	—	—	—
12. Control Phase Effective Resistance (ohms)	470	338	315	864	196	250	250	232	9400	830	1590
13. Voltage Fixed Phase volts	26	26	28	18	18	26	26	18	115	115	115
Voltage Control Phase volts	40	26	28	36	18	26	26	18	300/150	115/57.5	115/5
14. Power Fixed Phase watts	3.4	2.0	2.5	1.5	1.65	2.7	2.7	1.4	9.1	16.0	8.4
Power Control Phase watts	3.4	2.0	2.5	1.5	1.65	2.7	2.7	1.4	9.1	16.0	8.4
15. Power Factor (Control Phase)		—	—	—	—	—	—	—	—	—	—
16. Operating Temp. Range (°C)	−54 +125	−54 +85	−54 +125	−54 +125	−54 +85	−54 +85	−54 +85	−54 +85	−54 +85	−54 +85	−54 +85

	DIEHL MANUFACTURING					
1. Company (See Buyer's Guide)						
2. Model No.	BBM1-1	B11M7-2	B15M13-2	FPE21L	FPE25L	FPE49L
3. Weight (oz.) Approx. length (inches)	1.5, 1.2	4.5, 1.5	7.3, 1.5	12, 1.7	24, 2.7	44, 4
4. Size	8	11	15	—	—	—
5. Frequency (cps)	400/60	400/60	400/60	400/60	400/60	400/60
6. Rotor Inertia (gm-cm²)	0.5	1.1	3.3	12.8	25.6	133
7. Stall Torque (in-oz)	0.2	0.4	2	1.7	12.5	25
8. Internal Damping (dyne-cm-sec)	21.7	25	366	337	2327	4750
9. No Load Speed (rpm)	6200	1085	3460	3400	0.011	0.028
10. Time Constant (sec)	0.023	0.044	0.009	0.038	3500	3500
11. Theo. Accel. at Stall (rad/sec²)	28500	25000	43000	9400	34500	13300
12. Effective Resistance Control Phase, (ohms)	390	5400	2160	725	400	244
13. Voltage Fixed Phase (volts)	26	115	115	115	115	115
Voltage Control Phase (volts)	26/13	115/57.5	115/57.5	50	115	115
14. Power Fixed Phase (watts)	1.68	3.15	6.1	10	33	54
Power Control Phase (watts)	1.68	3.15	6.1	3.5	33	54
15. Power Factor (control phase)	0.81	0.74	0.76	0.70	0.76	0.71
16. Operating Temp. Range (°C)	−55 +75	−55 +75	−55 +75	−55 +75	−55 +55	−55 +55

	EASTERN AIR		
1.			
2.	S7HLZ3-6	S1H0Z7	S2HAX
3.	1.4, 0.84	4.0, 1.4	5.5, 1
4.	8	11	15
5.	400	1500	60
6.	0.66	1.1	3.3
7.	0.35	0.2	1.4
8.	36	5.4	360
9.	6700	25000	3000
10.	0.019	0.203	0.009
11.	37400	12900	34200
12.	226	220	2500
13.	26	35	115
	26	35	115
14.	3.0	5.5	5.5
	3.0	5.5	5.5
15.	0.75	0.60	0.70
16.	−55 +125	−50 +75	−40 +100

	ROTATING COMPONENTS, INC.				
1. Company (See Buyer's Guide)					
2. Model No.	15SB-108-1A1	18SA-100-1A1	08SA-104-1A1	10SB-105-1A1	11SA-106-1A1
3. Weight (oz.); Approx. Length (inches)	7.0, 1.55	12, 1.875	1.2, 0.9	1.7, 0.94	4.5, 1.47
4. Size	15	18	8	10	11
5. Frequency (cps)	60	400	400	400	400
6. Rotor Inertia (gm-cm²)	3.3	4.0	0.47	0.47	1.07
7. Stall Torque (in-oz)	1.4	2.3	0.2	0.28	0.6
8. Internal Damping (dyne-cm-sec)	589	320	21.8	18.8	65
9. No Load Speed (rpm)	1600	4800	6200	10000	6200
10. Time Constant (sec)	0.005	0.012	0.021	0.024	0.017
11. Theoretical Acceleration at Stall (rad/sec²)	30000	39700	30000	44000	39450
12. Control Phase Effective Resistance (ohms)	3250	1460	640	518	3800
13. Voltage Fixed Phase volts	115	115	26	115	115
Voltage Control Phase volts	115/57	115/57	40	36	115/57
14. Power Fixed Phase watts	4.0	9.0	2.5	2.5	3.6
Power Control Phase watts	4.0	9.0	2.5	2.5	3.6
15. Power Factor (Control Phase)	0.78	0.43	0.77	0.72	0.575
16. Operating Temp. Range (°C)	−55 +125	−55 +125	−55 +125	−55 +125	−55 +125

	BARBER-COLMAN		
1.			
2.	AYAE-278-715	DYAE-222-715	DYAE-478
3.	11, 1.9	18, 2.2	60, 3.7
4.	—	—	—
5.	60	60	60
6.	7.04	11.15	113
7.	0.96	1.6	6.4
8.	—	111	874
9.	2680	2810	3390
10.	—	0.10	0.13
11.	9660	9466	3980
12.	640	400	150
13.	115	115	115
	103	133	340
14.	6.4	7.4	26.8
	5.2	6.0	13.3
15.	—	—	—
16.	−18 +38	−18 +38	−18 +38

	CEDAR ENGINEERING			
1. Company (See Buyer's Guide)				
2. Model No.	S5000	S8008	S10011	S11002-4
3. Weight (oz.); Approx. Length (inches)	0 6, 0.700	1.5, 0.860	2.0, 0.869	4.0, 1.265
4. Size	5	8	10	11
5. Frequency (cps)	400	400	400	400
6. Rotor Inertia (gm-cm²)	0.16	0.50	0.50	1.05
7. Stall Torque (in-oz)	0.10	0.20	0.28	0.60
8. Internal Damping (dyne-cm-sec)	7.3	21.7	18.5	65.9
9. No Load Speed (rpm)	9500	6200	10000	6200
10. Time Constant (sec)	0.022	0.023	0.027	0.016
11. Theoretical Acceleration at Stall (rad/sec²)	44000	28200	39500	40300
12. Control Phase Effective Resistance (ohms)	415	6620	901	3780
13. Voltage Fixed Phase volts	26	115	26	115
Voltage Control Phase volts	26	115	52	115
14. Power Fixed Phase watts	1.63	2.0	3.0	3.5
Power Control Phase watts	1.63	2.0	3.0	3.5
15. Power Factor (Control Phase)	0.872	0.726	0.721	0.575
16. Operating Temp. Range (°C)	−55 +125	−55 +125	−55 +125	−55 +125

	NORDEN DIV., UAC			
1.				
2.	008E2B	101E2J5	105E1C	108E2B7
3.	1.5, 1.4	4.5, 2	8, 1.8	13.2, 2.5
4.	8	11	15	18
5.	400	400	60	400
6.	0.414	1.07	3.3	4.0
7.	0 25	0.45	1.45	2.35
8.	25.6	48.5	303	330
9.	6500	6200	3200	4800
10.	0.016	0.022	0.010	0.012
11.	42700	41500	31000	39700
12.	393	2645	2167	8460
13.	26	115	115	115
	26	115	115	282
14.	1.72	5.0	6.1	9.2
	1.72	5.0	6.1	9.4
15.	—	—	—	—
16.	−55 +204	−55 +204	−55 +204	−55 +204

AMERICAN ELECTRONICS

	8M10D-11A	10M09L-01A	SM11D2T	SM11A1T	SM12N97	SM13D9T	SM14D2T	11M50H-11J	15M22C-01A	SM18E	18SM6A-1
1.	1.8, 1.2	2.1, 1.1	4.5, 1.4	4.5, 1.4	4.2, 1.5	4.5, 1.4	4.5, 1.4	4.5, 1.4	2.3, 1.6	14, 2.562	17, 2.4
2.	8	10	11	11	12	13	13	11	15	18	18
3.	400	400	400	400	400	400	400	400	400	400	60
4.	0.25	0.7	1.07	1.07	1.07	1.07	1.07	1.07	3.0	3.3	5.2
5.	0.29	0.27	0.65	0.63	0.9	0.63	0.63	0.15	1.50	2.7	2.5
6.	—	—	—	—	—	—	—	—	—	—	—
7.	6000	10000	6000	6200	6000	6200	6000	6000	5000	10800	3000
8.	0.0077	0.037	0.015	—	—	—	—	0.063	0.0148	—	—
9.	82000	27200	41500	41500	59000	41500	41500	9900	35300	62000	34000
10.	290	640	3680	3680	78	3680	3680	726	2200	23	1322
11.	26 30	115 40	115 115	115 115	115 20	115 115	115 115	26 33	115 115	115 24	115 115
12.	3.1 3.1	2.5 2.5	3.6 3.6	3.6 3.6	5.1 5.1	3.6 3.6	3 6 3 6	1.5 1.5	6 6	23.2 25.2	10 10
13.	0.52	0.72	0.58	0.58	0.58	0.58	0.58	0.575	0.50	0.672	0.81
14.	−55 +125	−54 +125	−55 +150	−55 +150	−55 +125	−55 +160	−55 +105	−54 +125	−55 +125	−55 +90	0 +250

MUIRHEAD INSTRUMENTS

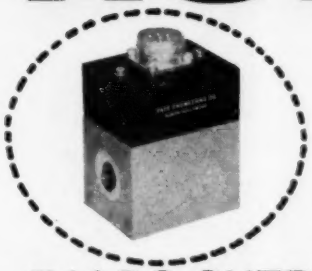
	08M10C1	10M10A1	11M10A3	11M10A11	15M10A2	15M10A4	18M10A2	18M10B4
1.	1.2, 0.84	1.5, 0.92	4.5, 1.6	4.5, 1.6	8, 1.6	8, 1.6	13.2, 2.02	13.2, 2.02
2.	8	10	11	11	15	15	18	18
3.	400	400	400	60	400	60	400	60
4.	0.13	0.46	1.1	1.1	3.1	3.1	4	4
5.	0.2	0.3	0.63	0.63	1.45	1.5	2.35	3.5
6.	21.7	32	68.7	68.7	193	310	333	800
7.	6800	6500	6200	3300	4800	3300	4800	3300
8.	0.006	0.015	0.016	0.016	0.016	0 01	0.012	0.005
9.	110000	46000	41000	41000	32000	34000	42000	61000
10.	240	418	457	225	65	2450	44	1322
11.	26 26/13	115 36/18	115 40/20	115 26/13	115 20/10	115 115/57.5	115 20/10	115 115/57.5
12.	2.8 2.8	3.1 3.1	3.5 3.5	3.0 3.0	6.1 6.1	5.4 5.4	9 9	10 10
13.	0.59	0.66	0.5	0.82	0.47	0.94	0.48	0.87
14.	—	—	—	—	—	—	—	—

GIANNINI CONTROLS

1.			
2.	DCM 8-1-1	DCM 8-1-2	DCM 20-1-1
3.	1.2, 1.5	1.2, 1.5	9, 1.26
4.	8	8	20
5.	DC	DC	DC
6.	2.6	2.5	65
7.	0.938	0.938	8.94
8.	18.1	17.6	2048
9.	22000	22000	2300
10.	0.086	0.086	0.0246
11.	26700	26700	9800
12.	8	31.1	20
13.	—	—	—
14.	—	—	—
15.	—	—	—
16.	−55 +95	−55 +95	−55 +71

PACE

MODEL CP53D



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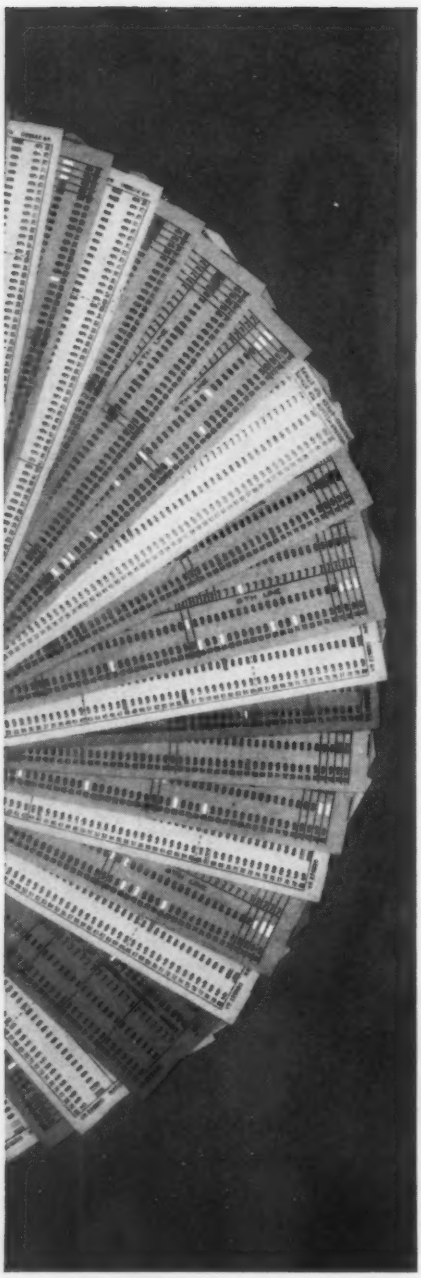

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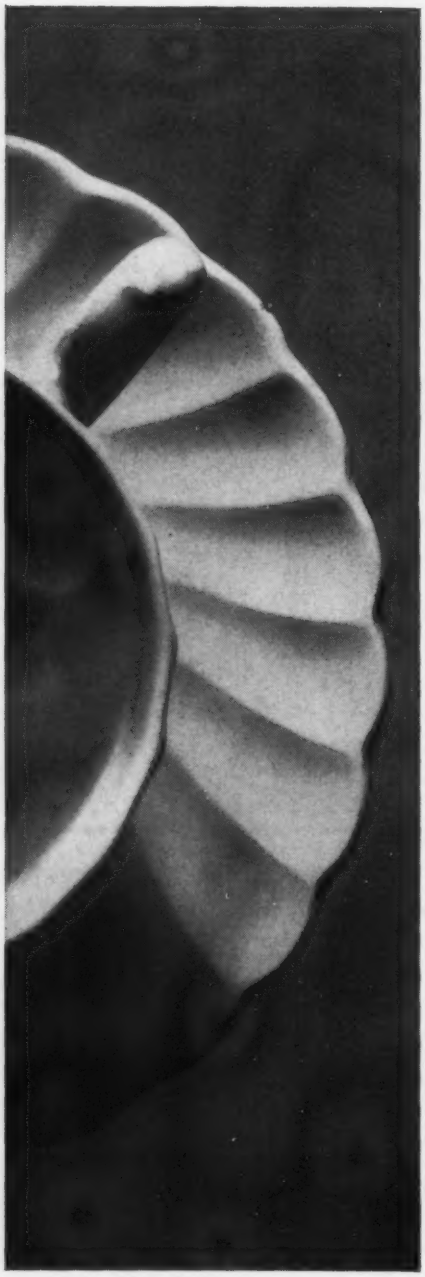

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CIRCLE NO. 40 ON INQUIRY CARD

COMPONENTS DIGEST 23

by William H. Barr
Contributing Editor

INTEGRATORS

Integrators have been devised in many forms and for a wide range of applications in both industrial and military equipment. They range in function from totalizing of material passing over a conveyor belt to extremely precise integration of acceleration signals to establish position information in inertial guidance systems. This Digest discusses the basic notion of integration, breaking the process down into its functional components, and describes the operation, performance and applications of a variety of important integrator types. Coverage of integrator types and manufacturers is not meant to be inclusive, but is based on extent of information received in response to an industry-wide questionnaire.

The process of integration may be regarded as the summing or accumulating of a physical quantity with respect to an independent variable. The rate of summing or accumulating is proportional to the value of the function being integrated. Let us illustrate this by an elementary example. Assume we have a function, $y=f(x)$, to be integrated with respect to x.

The quantity we are accumulating can be expressed as the area under the curve plotting $\{y=f(x)\}$ versus x over a specified range of x, while the rate of accumulating is proportional to the value of the function, $y=f(x)$, being integrated.

In practice, we may use as a basis for integration any convenient quantity that can be accumulated, where the rate of accumulation can be held proportional to the function to be integrated. The magnitude of the accumulated quantity will then be the integral of the function to be integrated. Figure 1 represents this process.

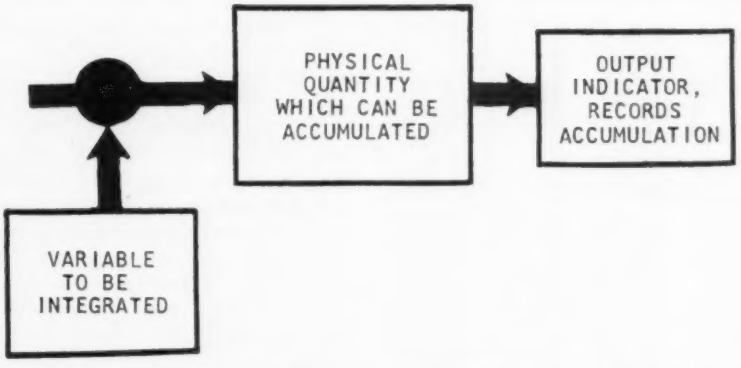


Fig 1 General form of an integrator. The variable to be integrated must be modified so as to provide an accurate control of the "flow rate" of the physical quantity being accumulated within the integrator. An output indicator records the summation. Accuracy of integration depends upon the proportionality between "flow rate" and the variable being integrated, and the accuracy of the output indicator.

Time Based Integrators

Solving for the integral of a variable with respect to time is the most common form of integration instrumented in engineering systems. Furthermore, other forms of integration are usually accomplished by modifying or combining time based integrators. The major portion of this Digest therefore covers the classification and description of time based integrators, and lists some of the major factors to be considered in their selection.

Instrumentation for other forms of integration and additional mathematical functions that can be accomplished by use of time based integrators will be discussed at the end of the Digest.

Since all time based integrators perform the same operation, they have the same formal characteristics. In each case, the integrand is given or mechanized in terms of the time rate of change of some quantity and the integral is obtained by sensing or measuring the cumulative magnitude

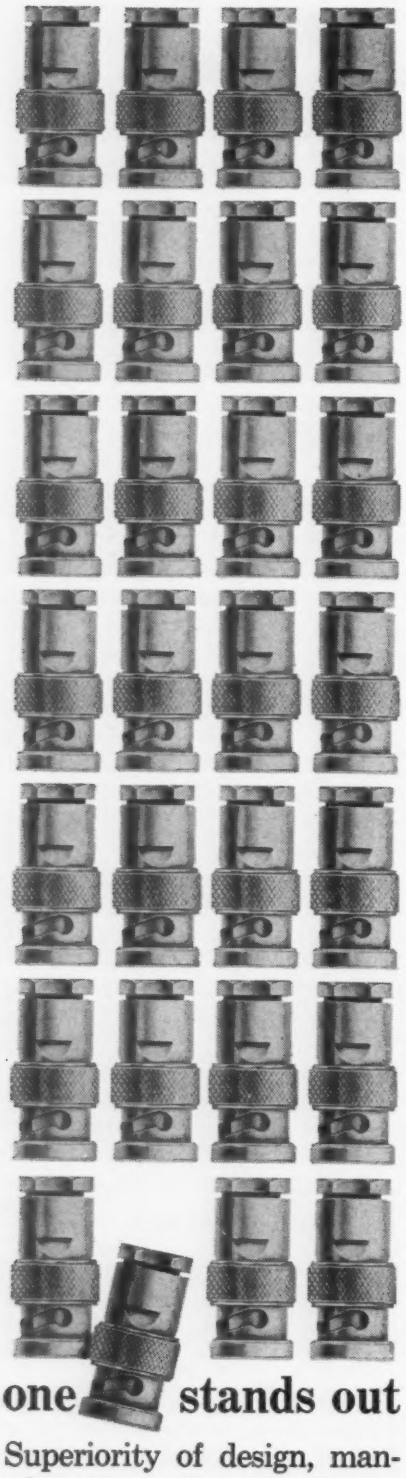
INTEGRATOR SELECTION FACTORS

ACCURACY:

- Linearity between the controlled rate of change of the accumulated quantity and the input signal.
- Accuracy of the output device that senses the accumulated quantity.
- Zero drift — accumulation of output in the absence of input signal.
- Constancy of scale factor over all operating conditions.

COMPATIBILITY:

- Form of input and output signals. (This factor is especially important where economy is a major consideration.)
- Maximum permissible values of the input (the variable to be integrated) and of the output (the integral).



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COMPONENTS DIGEST

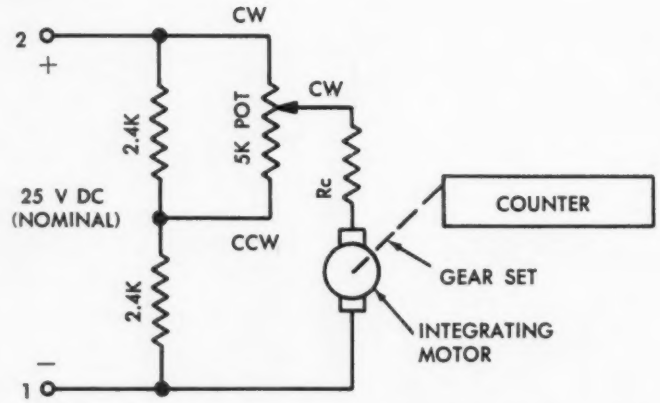

Fig 2 Circuit diagram of a dc motor integrator by GPE Controls, Inc.

of this quantity over the time period of interest.

For example, in many integrators, angular velocity of a shaft is used to represent the integrand, (that is, the integrator drives a shaft at a rate continuously proportional to the function or quantity to be integrated,) and an angle pick-off on the integrator shaft provides the desired integral by sensing the cumulative magnitude of shaft angle.

We will classify the integrators covered in this Digest according to the quantities used to represent the integrand, such as shaft velocity, voltage rate, or voltage frequency, and will describe the devices within these classifications according to the techniques used to make these quantities proportional to the integrand and according to the method used to sense the magnitude of the accumulated integral.

Shaft-Speed Integrators

A shaft speed integrator will designate any device in which shaft speed is controlled to be proportional to the integrand and the accumulated shaft angle represents or indicates the integral.

VOLTAGE INPUT

Where the input representing the integrand is in the form of an applied dc voltage, the simplest method of instrumenting a shaft-speed integrator is an open-loop system in which the input drives a dc motor with permanent magnet field at no-load speed, and a counter measures the accumulated shaft revolutions. Accurate open-loop performance is possible with this device because such a motor operating at essentially no-load speed tends to maintain its speed proportional to the applied voltage.

A typical integrator of this type is produced by GPE Controls for use in the process control field. To maintain ½% accuracy over a ten-to-one signal level, a high torque, low friction motor employing jeweled bearings and a precious metal commutator is used to drive a counter through a precision gear train. A schematic of this device is shown in Fig. 1. Some advantages of this system are its basic simplicity, ease of servicing, small size, reasonably good accuracy, and its ability to integrate a dc voltage directly. Some disadvantages are limitation to dc voltage inputs, sensitivity to large temperature changes unless temperature compensated, and inability to operate accurately at very low signal levels. Another disadvantage is that the dc motor speed is proportional to the absolute value of the applied voltage; the control signal must therefore be independent of line

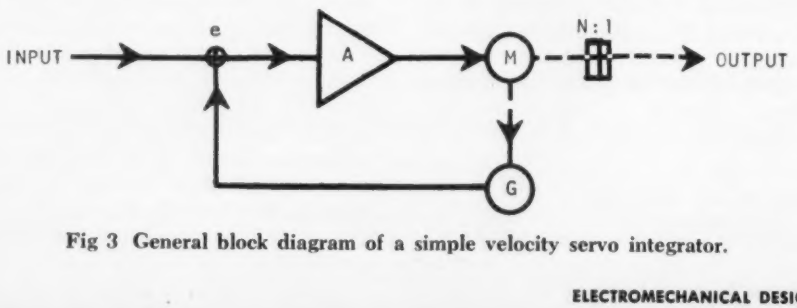

Fig 3 General block diagram of a simple velocity servo integrator.

voltage fluctuations.

Several methods are available for varying the scale factor of this type of integrator. One method, usually used for fine adjustment is by varying the setting of a voltage dividing potentiometer to reduce the signal to the motor. This method has the disadvantages of reducing sensitivity and accuracy. Sensitivity is reduced by applying only a portion of the control signal to the motor, thereby decreasing its torque output. Accuracy is reduced because the voltage divider tends to load the signal and to reduce the ratio of motor torque to friction causing poorer regulation. A second method of adjusting the scale factor of this type of integrator is to change the gear ratio between the motor and the counter. If we assume that the gear friction remains constant, changing gear ratios normally does not degrade the accuracy or sensitivity of the integrator. A third method of changing the sensitivity, of course, is by changing the motor to one having a different speed-voltage characteristic.

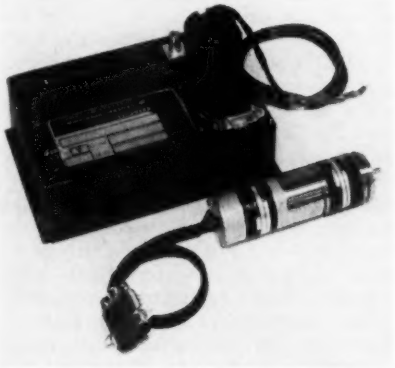

Fig 4 Simple velocity servo integrator by Kearfott, containing an ac drag cup tachometer, an ac amplifier, and a servo motor.

A more accurate type of shaft-speed integrator that can be designed to operate on either ac or dc voltage inputs uses a closed loop system to maintain proportionality between motor shaft speed and the input. The most common form of this type is a simple velocity servo which uses a tachometer to measure the output velocity of the motor shaft for comparison with the input signal. An error signal derived from this comparison is applied through a servo amplifier to drive the motor so as to null the error. Figure 3 is a block diagram of such a unit, and Fig 4 shows an ac model manufactured by Kearfott Co.

The scale factor of a velocity servo integrator may be changed by changing the gear ratio between the motor and the output shaft, modifying the control or tachometer feedback signal by means of a voltage divider, or changing the tachometer to one with different speed-voltage characteristic. Accuracy of a quality integrator of this type is typically of the order of 0.2% at ambient conditions and depends primarily on the accuracy of the tachometer. In ac units, the command signal is an ac voltage and the feedback element is an ac drag-cup tachometer. The feedback signal is usually proportional to the product of speed and line voltage, and the control signal is usually proportional to line voltage also, so that the system operates with negligible dependence on variations in line voltage. In dc units the command signal is a dc voltage, the feedback element is a dc tachometer, and the error signal is modulated to provide an ac driving voltage to a conventional ac servo motor. Since most dc tachometers employ permanent magnet fields and are independent of line voltage the dc integrator provides the integral of the absolute value of the control signal. The control signal therefore must be made independent of line voltage variations.

Relative advantages of ac and dc velocity servo integrators as listed by Kearfott Co. are

For a-c units:

- No brush problems such as arcing or noise (however, brush noise in dc units can usually be filtered out)
- No problems with ripple circuitry
- Lower starting torque required

For d-c units:

- Elimination of phase shift in tachometer output
- No residual voltage at zero speed
- Availability of high gradients in smaller size tachometers
- Easier temperature compensation
- Generally better linearity

A more accurate velocity servo integrator manufactured by Kearfott for ac or dc operation provides an addi-

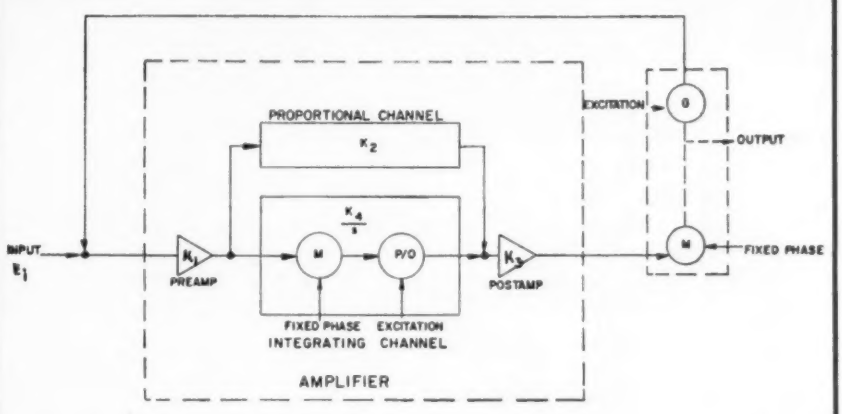

Fig 5 Block diagram of Kearfott's Infinite Gain Integrating Servo. Input signal E_i is fed through a preamplifier to drive a mechanical filter. The filter output is amplified by the post-amplifier. Output from the post-amplifier drives the motor generator at a speed level adjusted so that the tachometer output equals the command signal E_i. The transfer function for the amplifier is expressed approximately as:

$$KG(s) = K_1K_2K_4(1+T_s/S)$$

where K_4 = steady state gain of mechanical filter and $T = K_2/K_4$, which should usually be about the same as the time constant for the motor generator plus load. Kearfott says this system offers many advantages over the simple velocity servo used as an integrator. Coulomb friction and viscous friction, together with the inability of the motor to follow rapidly changing inputs due to the inertia at its shaft, contribute a substantial error voltage. This error can only be effectively decreased by raising the amplifier gain. But noise-sensitivity in high-gain amplifiers and phase shift of the tachometer output with changes of speed limit allowable amplifier gain. Kearfott minimizes these limitations in the system by the use of a mechanical filter thus permitting use of a high gain amplifier. The filter is a very-low-inertia motor with a torque proportional to the input voltage. The shaft drives into a low-noise-induction potentiometer through a very heavy viscous restraint. This high degree of restraint reduces coulomb and inertial effects at the filter shaft to a minimum. Thus the filter performs substantially as an integrator. Starting voltage of the filter is 0.250 volts. If the preamplifier has a voltage gain of 350, the error signal, or system sensitivity, will be 0.250/350 or 0.00072 volts.

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COMPONENTS DIGEST

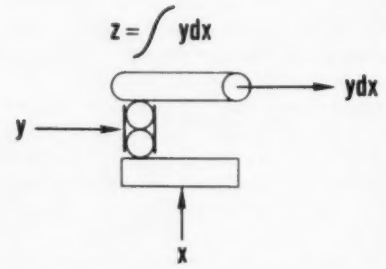

Fig 6 Schematic diagram of a ball disc integrator. In normal operation, disc rotation constitutes one input to the integrator. The two steel balls that separate the disc from the output roller are positioned to attain a second input. By spring loading the disc against the balls, disc rotation is transmitted by the balls to the roller. Rotational rate of the roller is then proportional to the speed of the disc and the radius at which the balls contact the disc. For a given disc speed, zero rotational rate of the roller occurs when the balls are over the center of the disc and maximum rotation rate occurs when the balls are at the maximum radius of the disc. Rotation is in opposite directions on each side. The diagram represents the solution of the equation $Z = 1/r \int y\,dx$. Ball-carriage position is the function $y = f(x)$. Disc angular velocity represents the quantity x; and $1/r$ represents the integrator constant where r is the output roller's radius in inches. If the quantity y is being integrated with respect to some quantity x that varies with time, then disc speed, as well as carriage position, will be varied as an input. But where y is being integrated with respect to time, the disc is driven at constant speed.

tional integration in the forward loop in the form of an electromechanical filter that effectively averages out noise in the error signal. This noise reduction allows use of a high gain amplifier that substantially reduces error voltage and improves accuracy. Figure 5 is a block diagram and a more detailed description of the performance of this unit, which Kearfott calls an Infinite Gain Integrating servo.

In specifying a velocity servo integrator for a given application Kearfott suggests inclusion of the following information:

- Size limitations, including space available for amplifiers and motor generators, and any special mounting requirements.

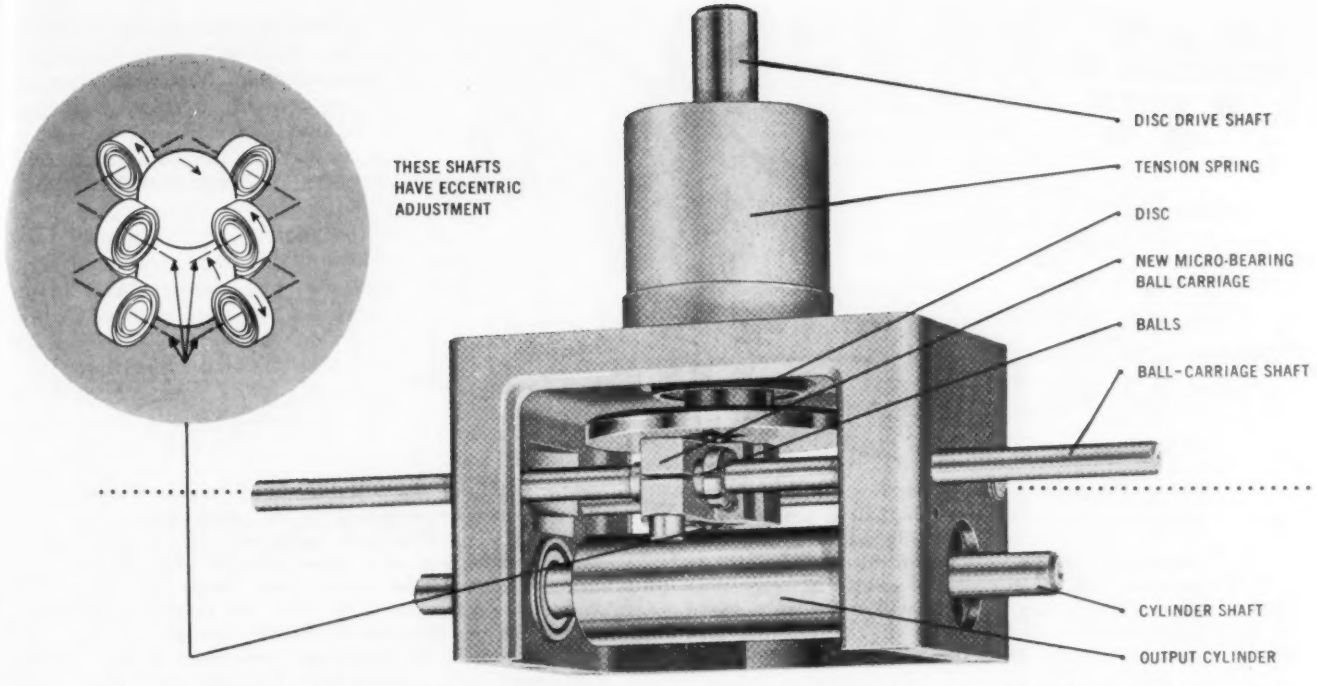

Fig 7 Librascope's high-torque ball and disc integrator features an adjustable microbearing ball carriage whose rolling action minimizes sliding friction, inherent in conventional sleeve-type carriages, and greatly increases the integrator's torque delivery and useful service life. A technique is provided for constraining the balls more accurately than is possible with nonadjustable types, which rely on machining to maintain tolerances. Operation of the integrator may be slowed or stopped in mid-solution without affecting accuracy. Performance characteristics include: accuracy 0.05% of full scale, reproducibility 0.01% of full scale, maximum recommended load 3.0 in-oz, life expectancy 10,000 hrs.

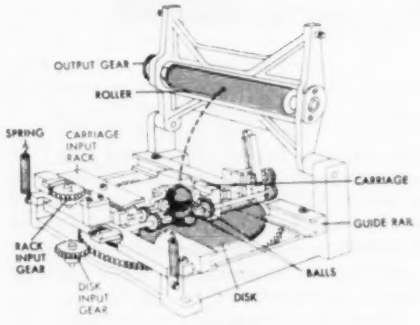

Fig 8a

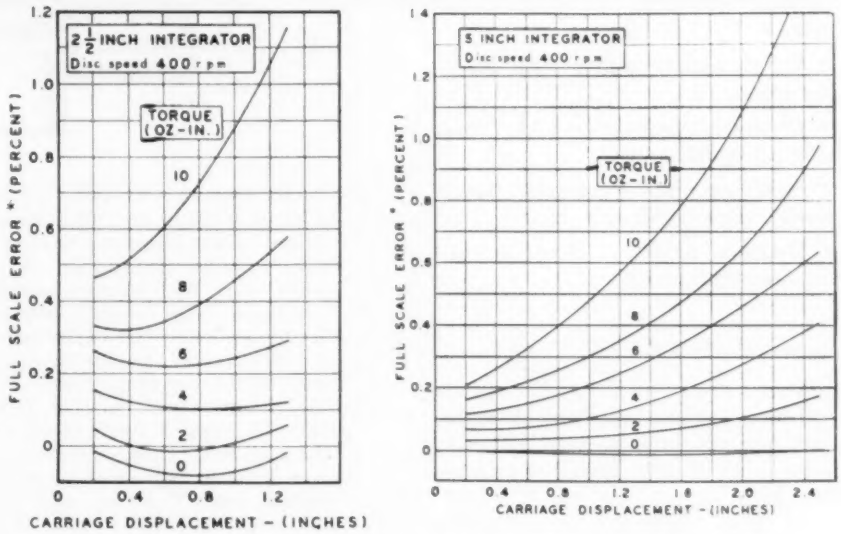

Fig 8b Error Curves. Full Scale Error equals: Theoretical rpm at a given carriage position minus actual rpm at that carriage position, with the difference *divided by* theoretical rpm at maximum displacement of the carriage.

Fig 8 Schematic diagram of a Ford Instrument Company ball disc integrator with roller assembly raised to show internal structure is shown in Fig 8a. Accuracy is emphasized in Ford Instrument designs. Standard units have a patented ball-roller-tilt device that minimizes ball slip for all carriage positions. A spring loaded roller permits rigid disc alignment. Use of similar materials permits tight fits without adverse effects in extreme temperatures. Vibration problems are eliminated since the roller is movable along the center of gravity and therefore is dynamically balanced. Identifying their models by maximum ball carriage travel, Ford Instrument describes three standard models: a 5 inch unit weighing 10.1 lbs, a 2½" unit weighing 6.0 lbs and a ½" unit weighing 14 ozs. Major performance characteristics of the ½" unit for maximum recommended roller output torque of 0.25 oz-inch are: accuracy in percent of full scale 0.1%, repeatability in percent of full scale 0.02%, input torque required 0.2 oz-inch. Figure 8b describes the performance of the larger units.

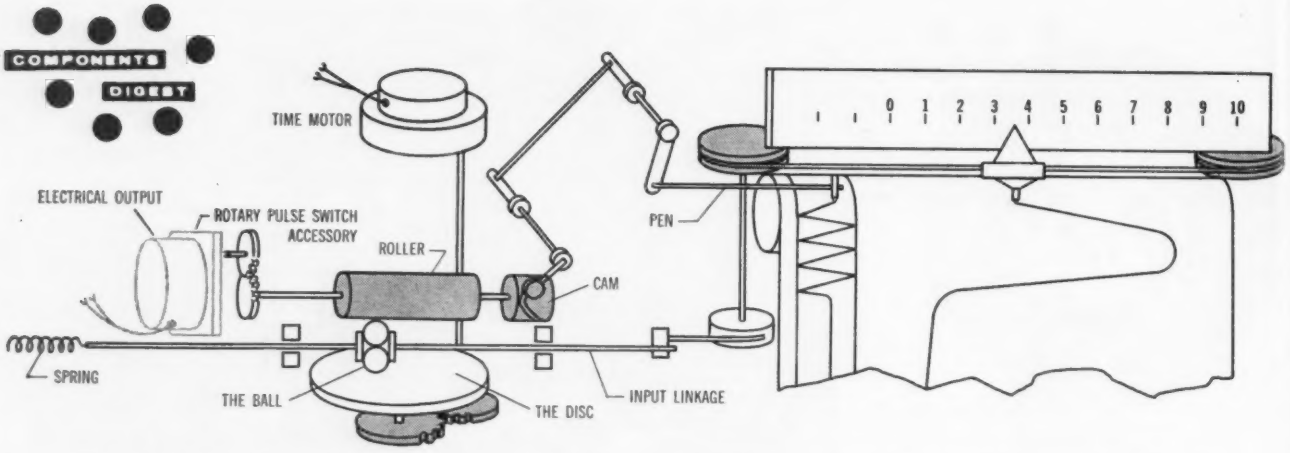

Fig 9 Diagram showing operation of Disc Instrument's integrator-recorder. The ball is positioned on the disc at a distance from the center in the same relationship as the position of the recorder pen to the base line. If the disc is rotated at a constant speed (time) then the ball will rotate at a speed proportional to the position of the recorder pen from zero — provided the recorder zero and the center of the rotating disc have been exactly aligned. This speed is transmitted to the roller which, by means of a "spiral in" and "spiral out" cam, actuates the integrator pen at a speed directly proportional to the position of the recorder pen. Since the entire load of the integrator is the back and fourth motion of the pen the difference in loading imposed by the pen lies within the maximum inaccuracy of 0.1% full scale.

- Environmental conditions – special attention to ambient temperatures and availability of heat sinks and cooling air.
- External load – static, viscous, inertial.
- Power supply – voltage and frequency regulation, harmonic distortion.
- Input signal – source impedance, distortion.
- Output requirements – scale factor, gearing, speed range.
- Static accuracy – accuracy during steady state conditions.
- Dynamic accuracy – accuracy during transients.

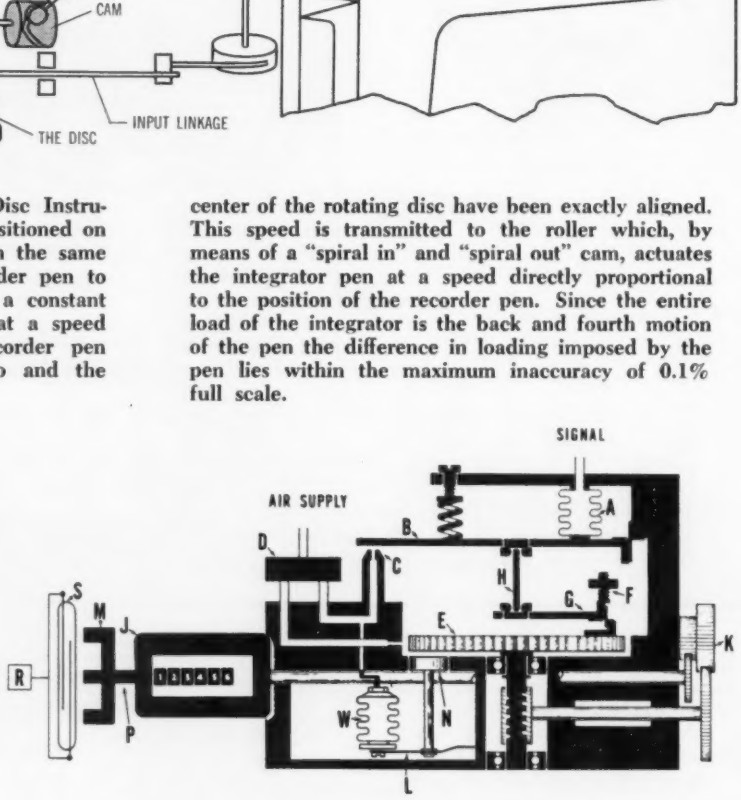

Fig 10 Pneumatic integrator by the Foxboro Co. A 3-15 psi signal, proportional to 0-100 percent of differential pressure from a flow transmitter, is applied to the integrator receiver bellows(A). The force exerted by the bellows positions a force bar (B), which acts as a flapper, in relation to a nozzle (C). With increase in differential pressure the flapper approaches the nozzle. The resulting increase in nozzle back pressure regulates — through air relay (D) — the jet which drives turbine rotor (E). Weight (F) is mounted on the flexure-pivoted bell crank (G). As the rotor revolves, the centrifugal force of the weight (F) is applied to force bar (B), through thrust pin (H), to balance the force exerted by the bellows (A). Therefore a condition of force balance is continuously maintained. The centrifugal force is proportional to the square of the rotor speed. This force balances the signal pressure which is proportional to the square of the flow rate. Therefore, rotor speed is directly proportional to flow rate. And, since the counter (J) is connected to the turbine rotor through gear train (K), total integrator count is directly proportional to the total amount of liquid that has passed the measuring point. In normal operation, the nozzle is partially covered and the resulting back pressure expands brake bellows (W) to hold the brake pad (N) off the rotor. If the transmitter signal decreases suddenly — anywhere within the signal range — the brake bellows contracts, and spring lever (L) forces the brake pad against the rotor. This action momentarily slows down the rotor until a balance of forces is restored at the new signal pressure. And, if the transmitter signal drops to minimum, 3 psi, the bellows contracts, completely stopping the rotor. The brake brings the rotor, hence the counter, from full speed to stop in less than one second.

MECHANICAL INPUT

Many shaft-speed integrators are provided with a mechanical input. The general form of most of these units, when used to integrate a quantity with respect to time, is a constant speed motor driving a variable speed transmission controlled so that the speed of the output shaft is proportional to the displacement of a mechanical input. A most simple and accurate device of this type is the ball disc integrator illustrated and described in Fig 6.

As the name implies, the integrator consists of a spring loaded disc, two constrained steel balls, and an output roller. The diagram illustrates that when the disc is driven at a constant speed, the device is a linear variable speed transmission in which the speed of the output roller shaft is proportional to the radial position of the balls with respect to the center of the disc. If this position of balls is used to represent the input (the integrand) then the accumulated angle of roller shaft will express the integral. This angle is often indicated in terms of shaft revolutions by means of a counter.

To design a precision integrator using this design concept requires

careful selection and processing of component parts. The disc must be extremely hard and lapped to a mirror finish to resist wear. Librascope Div. of General Precision Inc. points out that the method used to constrain the steel balls has a significant effect on output torque delivery and life of the unit. Figures 7 and 8 show and describe some of the special characteristics of standard ball and disc integrators manufactured by Librascope and by Ford Instrument Co.

In specifying a ball disc integrator for a given application Librascope recommends the following information be supplied:

- Environment
- Input functions
- Input and output load and speeds
- Use (variable speed device, computing element)
- Life required
- Accuracy and reproducibility required.

They warn that ball and disc integrators are limited in maximum disc input speeds to about 500 RPM and output speeds of approximately 1200 RPM, if satisfactory life is expected from the unit.

Ball-disc integrators are most useful when mechanical inputs are available and mechanical output is desirable. General advantages of mechanical integrators are ruggedness, relative low cost, ease of design into a system, reliability, and minimum maintenance. Another distinct advantage of ball-disc integrators is that the mechanical integrator may be stopped in mid-solution without affecting accuracy.

The principal disadvantage of a ball-disc integrator is that torque output, which depends on roller friction, is limited to a few oz-inches where high precision is required.

In process control instrumentation integrators are often combined with chart recorders to provide a record of the integral of a quantity in relation to the quantity. Figure 9 shows and describes such equipment manufactured by Disc Instruments Inc. They use a ball-disc integrator in which the ball position input is actuated by a linkage from the recorder pen assembly and the roller output is digitized and recorded on the chart by a cam-and-pen-linkage assembly.

PRESSURE INPUT

In flow measurement equipment where differential pressure between the throat of a venturi and the fluid line pressure is used to sense flow rate, integrators are required to provide indication of total flow. But since flow rate is proportional to the square root of differential pressure, the inte-

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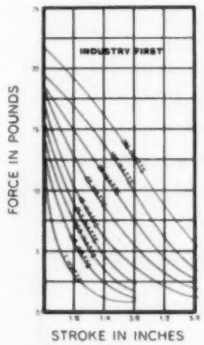
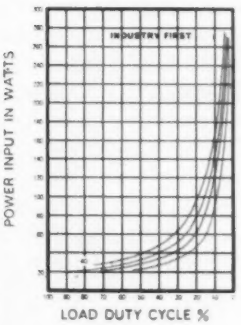
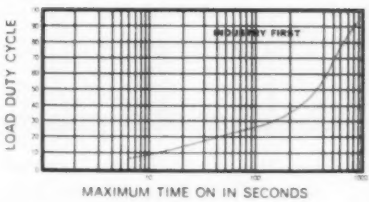


STEP 1
FORCE STROKE
Curves at Rated Loads



STEP 2
LOAD DUTY CYCLE
Coil Rating vs Load Duty Cycle, %



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TYPICAL DATA

Rotation Rates:	150° and 300° per hour
Table Rate Stability:	0.2%
Table Axis Wobble:	10 arc sec. (max.)
Tilting Range:	±90°
Table Surface:	flat to 0.0001 (or better as required)
Power Requirements:	115 VAC, 60 cps 1 phase at 15 watts; 28 VDC, 0.52 amp.
Dimensions:	2′ long x 2′ high x 2′ in diameter

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KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

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COMPONENTS DIGEST

grator must provide a measurable quantity that accumulates at a rate proportional to the square root of the input. Although such devices are called pneumatic integrators, they are really computing mechanisms that perform a square root operation as well as integration.

Figure 10 describes a typical pneumatic integrator, manufactured by the Foxboro Co., that uses a shaft rate

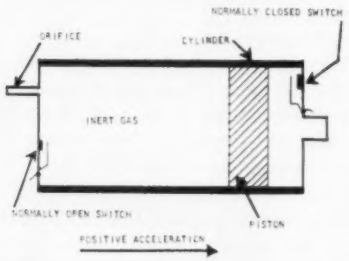


Fig 11 Dashpot integrator designed by Giannini Controls Corporation for use in an integrating accelerometer to indicate attainment of a prescribed velocity. Basically the integrator consists of a matched piston and cylinder. The cylinder is plugged at both ends and has an adjustable orifice in one end. The plugs are also provided with two switch contacts — one for normally closed (piston null position) and the other for normally open (piston maximum position). The system is filled with inert gas. When the piston (mass) senses an acceleration along the sensitive axis, the force, which is proportional to the product of mass and acceleration pushes the gas through the adjustable orifice. Integration is attained when the piston (mass) has been fully displaced from its null to the maximum position, closing the switch contact.

proportional to the square root of a differential pressure input to represent flow rate (the integrand). A counter on the shaft indicates total flow.

TORQUE INPUT

Single-degree-of-freedom integrating gyros use an exceedingly simple, yet highly accurate method of integrating. Input to the integrator portion of the gyro is in the form of a precesional torque on the gyro gimbal. Since damping torque of a rotary viscous shear damper is proportional to the angular velocity of the rotor, use of the damping torque of a fluid between the gimbal and the gyro case

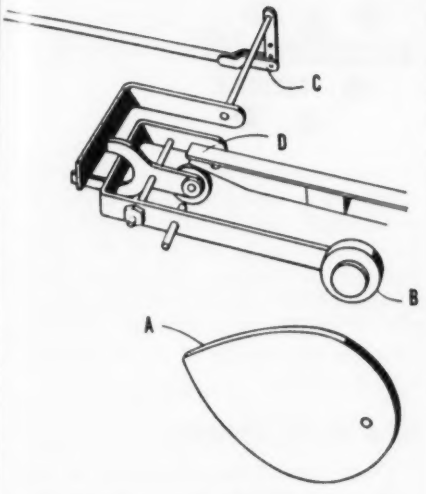
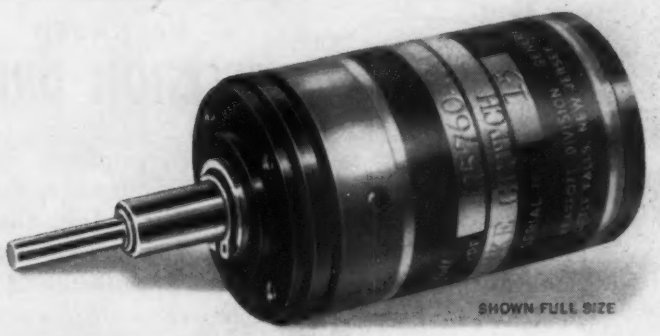


Fig 12 Schematic diagram showing operation of a Foxboro pulse width integrator. The cam switch assembly includes a cam rotated continuously, one revolution in 12 seconds, by a synchronous motor drive, and a cam follower B continuously positioned in proportion to the measured flow, through ball link C. Cam switch D operates the counter drive-motor. During the portion of each 12 second rotation when the follower is off the cam, the switch D is closed, the counter motor operates and the counter registers. When the cam follower again touches the cam, the counter switch is open and remains open until the follower again leaves the cam. There is no overspin nor start-up lag in the self-braking motor. During the period of 100 percent flow, the cam breaks the contact for 1/21 of the 12 second cycle (0.57 seconds) which allows for calibration of the counter and correct setting for maximum flow. The counter gear train corrects for the accumulative effect of the short interval of discontinuity. At flows below 10 percent of scale, the contact is continuously open and there is no count. The integrator may have a cam for a square root or for a uniform flow scale. The cam shown is for square root flow scale.

as the reaction torque to balance the steady-state input torque results in an angular velocity of the gimbal proportional to the balanced torque. Gimbal rate is integrated by means of a Microsyn signal generator that senses angular deviation of the gimbal output shaft. (Since the precesional torque generated by the gyroscopic element is proportional to the input angular velocity of the gyro, the Microsyn signal, being proportional to the integral of the precesional torque, is proportional to gyro angle input.)

FORCE INPUT

Where the input is in the form of a force rather than a torque, a fluid dash-pot, operating in the laminar flow range, can be used to maintain proportionality between rate of travel



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Typical applications involving these Size 11 magnetic clutches, brake clutches, and brakes include service as output controls in mechanical differential computers, as motor brakes, and as speed changers and uncouplers. Kearfott can also provide magnetic clutches, brake clutches and brakes in various other sizes to suit desired applications. Components also available in sizes 8 and 6 diameters.

CHARACTERISTICS

	Magnetic Clutches		Magnetic Brake Clutch	Magnetic Brake
Unit No.	**R5750-001**	**R5750-002**	**R5760-001**	**R5770-001**
Size	11	11	11	11
Power input (Watts)	3	3	3	3
Clutch Torque (In. Oz.)	6 (energized)		4 (energized)	–
Brake Torque (In. Oz.)	–	–	6 (de-energized)	16 (energized)
Inertia (gm cm²)	.82 (energized) .56 (de-energized)		.82 (energized) .56 (de-energized)	.34
Engaging Surfaces	Steel	Brake Material	Steel and Brake Material	Steel
Environmental Performance	Per MIL-E-5272A			
Life (Cycles)*	3,000,000			

*1 Cycle=1 revolution of shaft engaged and 1 revolution of shaft disengaged, at 500 RPM.

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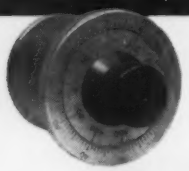

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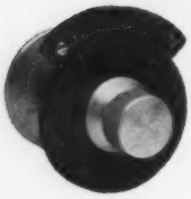

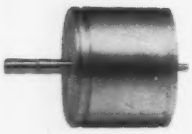

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of the piston and the input. Thus the integrand is represented by a translational shaft rate and the integral can be determined in terms of the total distance traveled by the piston shaft. Figure 11 describes an application of this principle by Giannini Controls Corp. in the design of an integrating accelerometer.

Pulse Width Integrators

Time based integration may be instrumented by use of a cam-switch device that controls a series of voltage pulses so that the ratio of "on" time to "off" time is continuously proportional to the variable to be integrated. Input to the integrator is in the form of a mechanical displacement. Measurement of accumulated "on" time by means of a motor driven timer actuated by the "on" pulses provides the time integral of the variable. Accuracy of the device is independent of pulse rate, although the rate is usually held approximately constant. Because of their simplicity, low cost and reliability, pulse width integrators are used widely in process control industries, usually in association with a chart or disc recorder. They can be easily adapted to provide the integral of the function of a variable by proper shaping of the cam.

Figure 12 is a schematic diagram illustrating the operation of a typical pulse width integrator.

Pulse Rate Integrators

If the pulse repetition rate or frequency of a signal is made continuously proportional to a quantity to be integrated, a count of total pulses or cycles will represent the integral. Many devices are available on the market to convert a varying analogue voltage to a continuously proportional frequency or pulse rate. A typical device of this type employs a saturable magnetic circuit that saturates at a rate proportional to an input voltage and is self resetting after saturation so that a continuous series of pulses is produced. Such a device driving a pulse counter will indicate the time integral of the input voltage over the elapsed operating time.

Another type of integrator operating on this principle is described in an article entitled "Oscillator Computer" in the August, 1960 issue of Electromechanical Design. The device described is a simple watch movement with a variable escapement

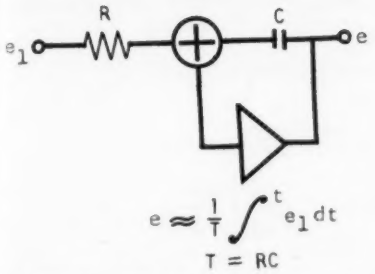

Fig 13 Simplified block diagram of an electronic integrator using an operational amplifier.

in which the restoring force on the balance wheel is provided by an equivalent magnetic spring. Effect of the equivalent spring is to continuously vary the oscillation frequency of the balance wheel in proportion to an input magnetizing current. A count of the balance wheel oscillations will indicate the integral of the input current. Although we have classified this device as a variable frequency integrator, the integration is actually performed by the escapement mechanism which transforms the oscillation rate to a shaft rate to provide the integral in terms of number of shaft revolutions.

Current Integrators

Current is a quantity expressing the rate of flow of electrical charges through a conductor. Thus, when a quantity to be integrated is given in the form of a d-c current, the integration can be performed directly by measuring the accumulation of matter transferred through an electrolyte by the current.

One such device consists of a capillary tube with electrodes and a quantity of mercury at each end and a small volume of electrolyte in the middle. As d-c current flows through the circuit, mercury from one side is transferred by the current through the electrolyte and deposited on the other side. As a result, the electrolyte moves along the tube in a direction corresponding to current flow and at a rate proportional to the current. Distance traveled by the electrolyte is therefore the time integral of the current. Resetting this type of device is a problem that must be dealt with in practical applications.

Another type of integrator for use where the input quantity is in the form of a dc current (or voltage) is a circuit device frequently called an electronic integrator. It consists of a very high gain dc amplifier (called an operational amplifier in the analog computer field), a precision input resistor and a precision feedback capacitor (see Fig 13). Voltage across the feedback capacitor represents the

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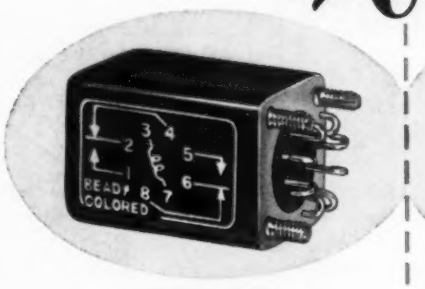

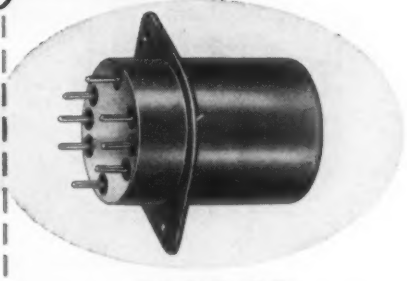

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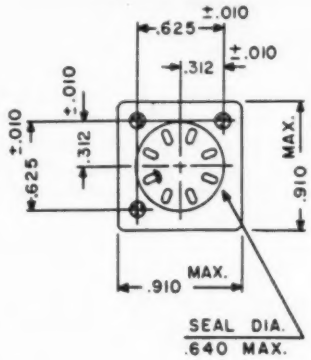

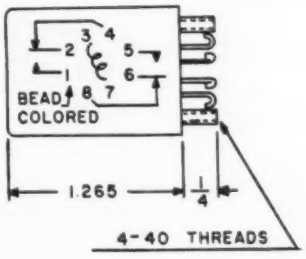

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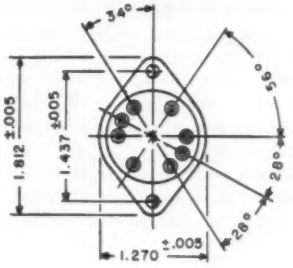

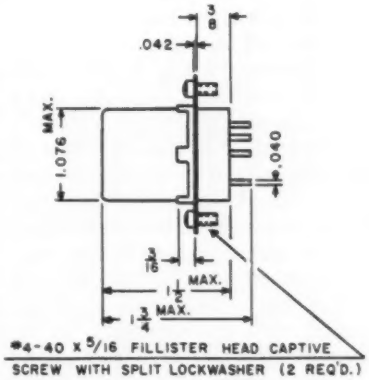

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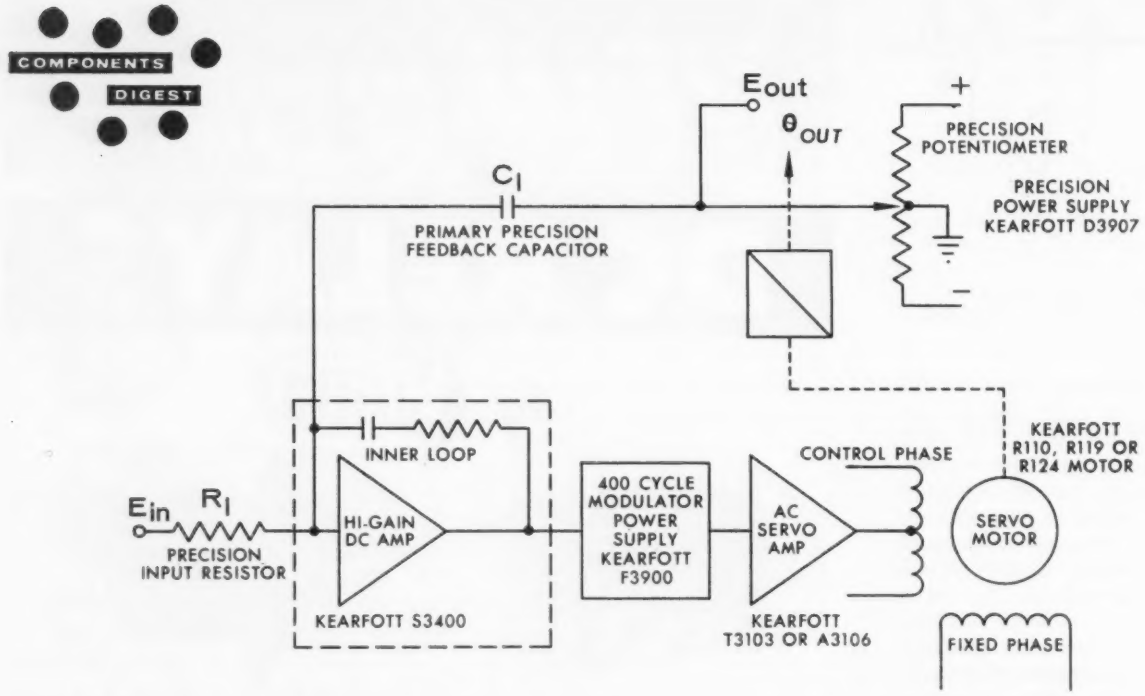


Fig 14 Block diagram of Kearfott's completely transistorized electronic integrator with the addition of electromechanical output in the form of a motor shaft position for driving slave potentiometers or other rotary devices. Maximum linearity error of the unit is 0.01% of indicated value; scale factor repeatibility is 0.01% for continuous operation and 0.03% for long term operation. In operation of the unit, as designed by Kearfott, output voltage seeks a value that causes feedback current to balance the input current flowing through R_1. Voltage across the capacitor C_1 is thus proportional to the time integral of the current. The output shaft maintains a position proportional to the output voltage. In addition to providing mechanical output, the motor driven pot introduces a second integration to reduce steady-state errors. Gain of the error signal is sufficiently high that system accuracy is almost entirely impendent on the *RC* product and its tolerance. The inner loop integrator provides a high, stable, dc gain to drive the error current to zero. The feedback capacitor in the inner loop is included to provide instantaneous feedback for sudden signal changes, thus preventing amplifier saturation and loss of accuracy.

integral of the input signal.

Operation of the circuit is as follows: Current flowing in the input resistor R produces a minute error signal to the amplifier input, which is greatly magnified by the amplifier to change the voltage on the output side of the feedback capacitor at a rate and polarity to drive the error signal (amplifier input) towards the null. In doing so, the current in the input resistor is channeled into the feedback capacitor, with the exception of insignificant error current that flows into the amplifier. This causes the voltage to build up across the feedback (or integrating) capacitor according to the time based integral of the input current.

Since the gain of the amplifier is extremely high, of the order of one million to one billion, the error current is so small that it has no measureable effect on accuracy. The characteristics of this type of integrator are independent of the amplifier gain, being dependent only on the values of R and C. The constant of integration can be set into the circuit by precharging the capacitor to the specified value.

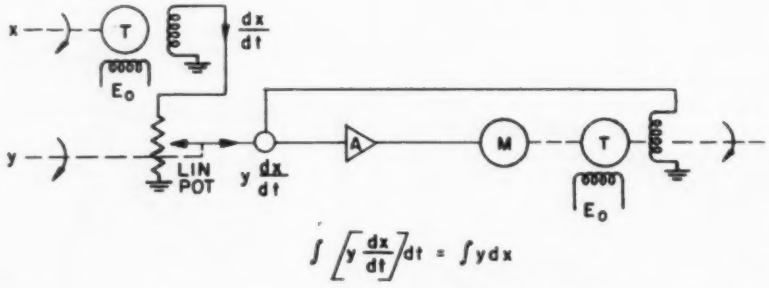


Fig 15(a) Integration of a variable with respect to a variable other than time (mechanical inputs)

George A. Philbrick Researches, Inc., who manufacture operational amplifiers for a wide range of applications, state that accuracies of 0.1% for short term operation and 1% over 14 hrs of operation are typical of high quality electronic integrators.

Kearfott Div. of General Precision Inc., describes an extremely accurate integrator based on the principle of the electronic integrator described above but with the addition of electromechanical position servo components that introduce another integration into the loop to reduce steady-state errors, and that supply the output in terms of a shaft position as well as a voltage.

Computing Applications

Time based integrators can be modified or combined to perform almost any mathematical operation. Some of the more common uses of velocity servo integrators in computing equipment are described by Kearfott in Fig 15.

In Fig 16, Ford Instrument Co. shows functional schematics of some typical computing operations that can be performed by ball disc integrators.

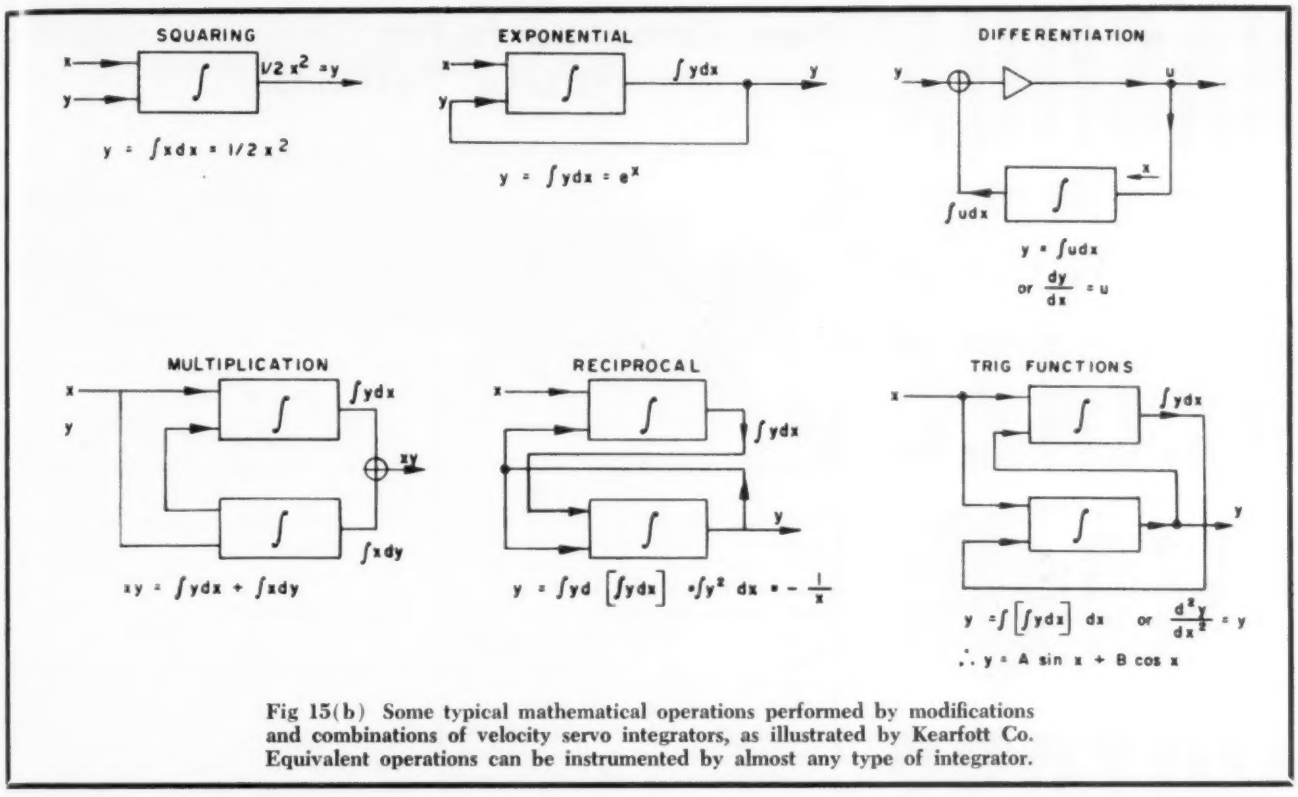

SQUARING
$y = \int x\,dx = 1/2\,x^2$
EXPONENTIAL
$y = \int y\,dx = e^x$
DIFFERENTIATION
$y = \int u\,dx$
or $\frac{dy}{dx} = u$
MULTIPLICATION
$xy = \int y\,dx + \int x\,dy$
RECIPROCAL
$y = \int y\,d\left[\int y\,dx\right] = \int y^2\,dx = -\frac{1}{x}$
TRIG FUNCTIONS
$y = \int\left[\int y\,dx\right]dx$ or $\frac{d^2y}{dx^2} = y$
$\therefore y = A \sin x + B \cos x$

Fig 15(b) Some typical mathematical operations performed by modifications and combinations of velocity servo integrators, as illustrated by Kearfott Co. Equivalent operations can be instrumented by almost any type of integrator.

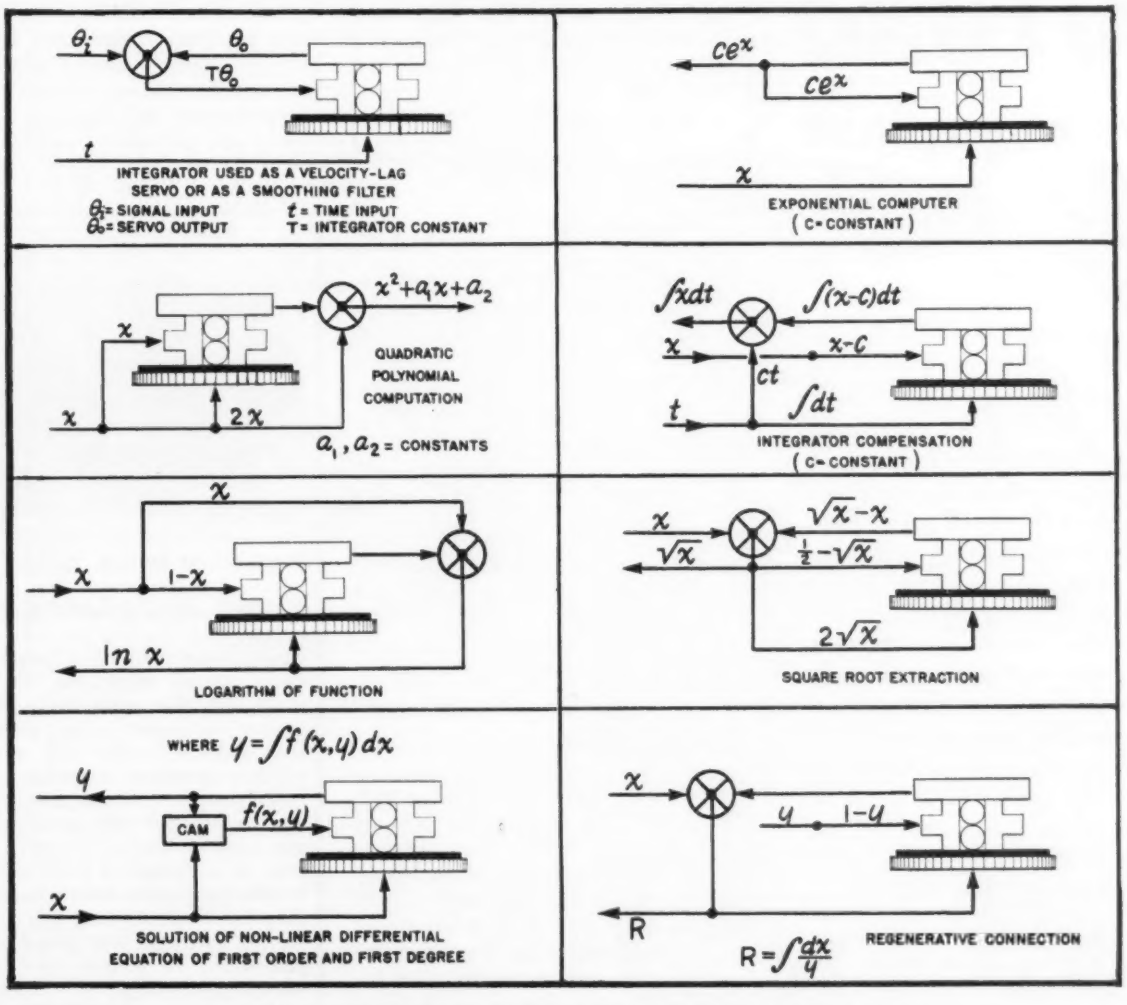

INTEGRATOR USED AS A VELOCITY-LAG SERVO OR AS A SMOOTHING FILTER
θ_i = SIGNAL INPUT
θ_o = SERVO OUTPUT
t = TIME INPUT
T = INTEGRATOR CONSTANT
EXPONENTIAL COMPUTER (C = CONSTANT)
QUADRATIC POLYNOMIAL COMPUTATION
a_1, a_2 = CONSTANTS
INTEGRATOR COMPENSATION (C = CONSTANT)
LOGARITHM OF FUNCTION
SQUARE ROOT EXTRACTION
WHERE $y = \int f(x,y)\,dx$
CAM
SOLUTION OF NON-LINEAR DIFFERENTIAL EQUATION OF FIRST ORDER AND FIRST DEGREE
REGENERATIVE CONNECTION

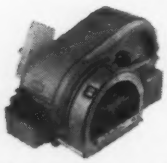
Fig 16 Functional schematics of some typical computing operations using ball-disc integrators, as illustrated by Ford Instrument Co.

NASHUA

approves high starting torque of

HEINZE SMR MOTORS

for new tape dispenser



Nashua Corporation's Vuematic tape dispenser which provides ready-to-use high quality sealing tape in positive lengths, relies on a motor with high starting torque. The Heinze SMR Universal Motor supplies this — plus long life. External brushes are easily accessible. Company executives state, "Our people in service, manufacturing and sales all endorse these fine motors which have been used by us for several trouble-free years of operation." Heinze Universal Motors are compact, have high starting and running torques, are versatile to allow all types of mounting arrangements and modifications, are uniform in quality, keyed to high production, and are competitively priced.

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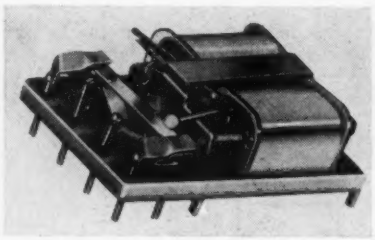

Printed Circuit Relay

Positioning the header 90° to a side mounting configuration achieved a low profile for a new micro-miniature relay. Seated height is only 0.45 in. Both connector pins and mounting posts extend through the component board, allowing ready accessibility from the opposite side. Dry circuit current requirements are 1 microamp at 1 mv with 100 ohm max. contact resistance. Three amp contact rates at 32 resistive load; and 5 millisecond max. operate/release time. Life tests, at full load and 125°C, have exceeded 100,000 operations. Unit meets MIL-R-5757D. Babcock Relays, Costa Mesa, Calif.

Write No. 541 in Box on Inquiry Card

Centrifugal Switch

Used for speed sensing, overspeed and underspeed detection, speed interlocking, sequencing and signaling, new centrifugal switch with negligible friction provides repetitive accuracy. Weights fasten directly to a simple one-piece spring steel disc. Centrifugal force of the weights overçomes the rapid decrease in spring force, resulting in snap action at operating speed. Normal operating speeds range from 900 to 4,000 rpm and standard units operate at 1,000 and 2,200 rpm. Square D Co., EC&M Div., Cleveland, Ohio.

Write No. 319 in Box on Inquiry Card

Lightweight Motors

Incorporating aluminum alloys, standard integral hp motors are said to weigh up to 30% less than cast-iron motors on a rating-for-rating basis. Bearings are pre-stacked and double shielded. A built-in protector makes it virtually impossible to burn out the motor; it also eliminates the need for expensive motor starting equipment. Franklin Elec. Co., Inc., Bluffton, Ind.

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A-D Encoder

Analog-to-digital shaft position encoders based upon the Gray Code format are available in ranges from 2^5 to 2^{13}. Precious metal alloy code drums are utilized in lieu of etched or plated discs. Multi-strand wipers are used on each track to increase reliability and to reduce noise. Units satisfy or exceed all applicable requirements of MIL-E-5272 and MIL-T-5422. Northern Precision Laboratories, Inc., Franklin Lobes, N. J.

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Crystal Filters

A high selectivity, high attenuation 1 kc crystal filter is said to be nominally priced to make it available in as many applications as possible. Heretofore, it was believed virtually impossible to design a crystal filter that would meet critical specs at this frequency. Many types covering frequencies up to 30 Mc were similarly considered difficult to design but are now also available at moderate cost. Burnell & Co., N. Y.

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Snap-action Switch

"Cricket" action is used in the contact-carrying leaf spring of a new subminiature snap-action switch. Uniform stress distribution achieved throughout the spring reduces metal fatigue and results in long switch life with high reliability and continued uniform operation, according to the manufacturer. Switches are rated 5.0 amps at 125-250 volts ac on inductive and resistive loads, 4.0 amps at 30 volts dc on inductive loads to 50,000-ft altitudes. Basic switch weighs less than 0.080 ounce. Unit has only two moving parts, the leaf spring and the pushbutton to actuate it. Fansteel Metallurgical Corp., N. Chicago, Ill.

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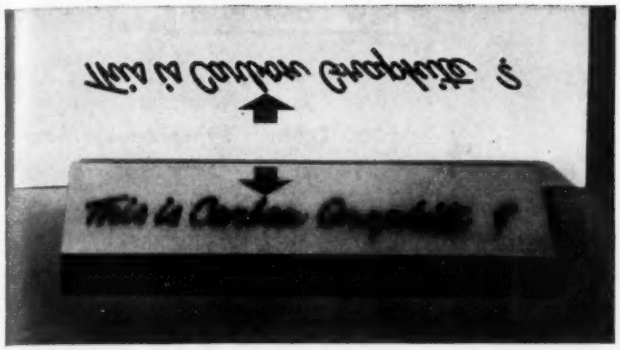

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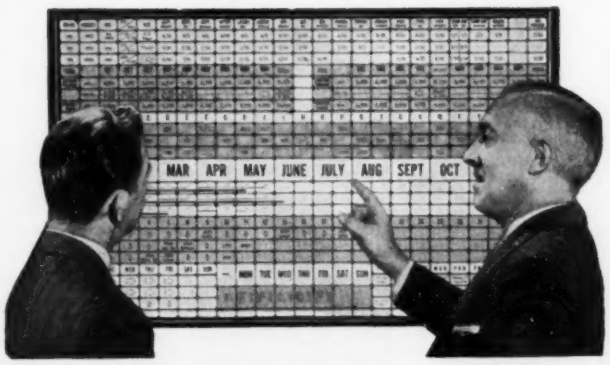

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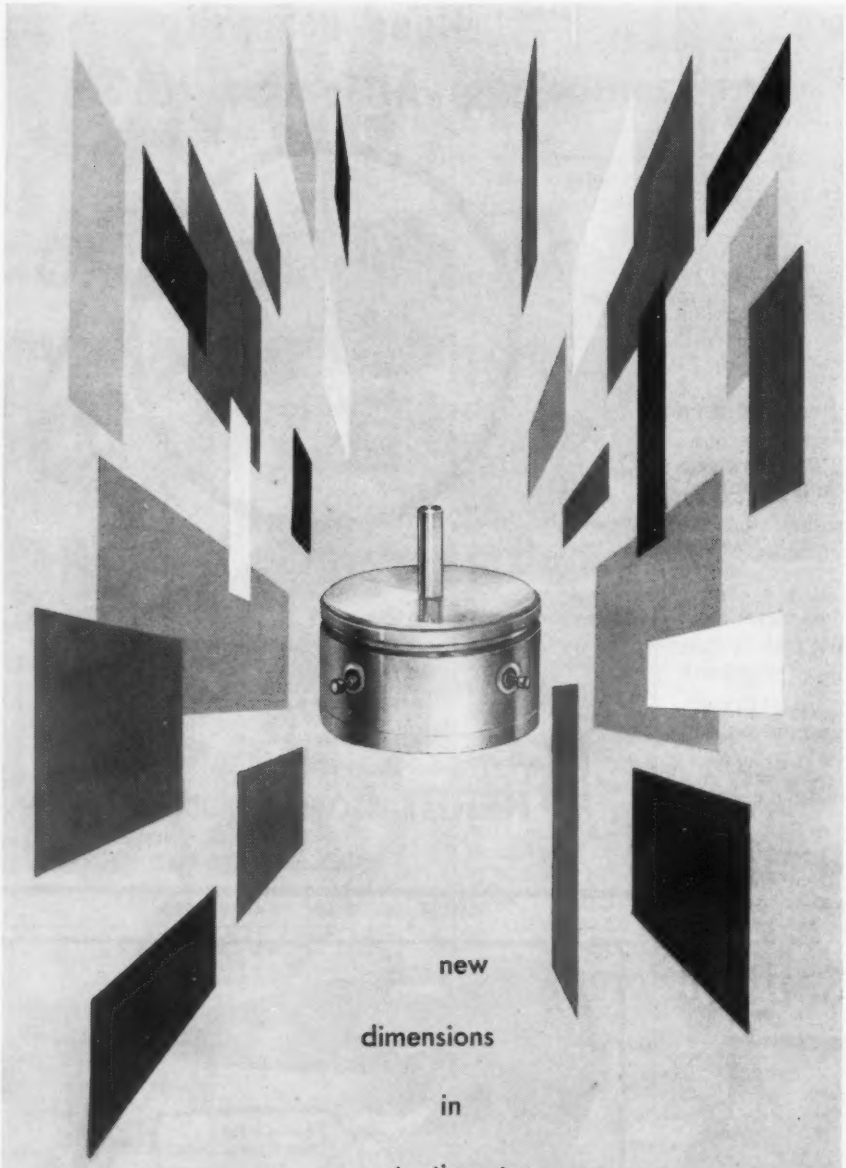

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NEW COMPONENTS

1000 Oz-Inch Synchronous Motor

For "on-off" ac servo applications where a 72 rpm speed and 1000 oz-inch torque are required, a motor type X1000 can be started, stopped or reversed instantly with a single-pole, three position switch. Output shaft can be stepped at 200 precise steps per revolution by using a dc power supply with appropriate switching. Other ratings include: input 120 v, 50/60 cycle, 1 phase, 3.0 amps max current (at 60 cycles). Unit conforms with Class 1, Group D explosion-proof specs. The Superior Electric Co., Bristol, Conn.

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Reversible Gearmotor

Instant reversing, high constant torques, low sound level, compact size and a wide range of output speeds (any individual speed from 0.3 rpm to 500 rpm) is provided in two new gearmotors. Units develop up to 250 in. lbs. at 10 rpm, and are available in 1/15 hp 220 v 3 phase and 1/15 hp 115 v single phase. Mounted in any position, these units are designed for business machines, automation equipment, pumps, conveyors, power take-offs, roll drives and other applications requiring high torques, small size and low cost. New England Gear Works Inc., Southington, Conn.

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Integrated Size 5 Servo

New integrated servo assembly contains a size 5 motor, a size 5 synchros and precision gearing (gear ratios up to 875:1 are available). Output shaft is geared 1 to 1 with a size 5 control transformer. Output shaft positions itself to agree with 3-wire electrical input data received from any synchro control transmitter. Complete assembly is integrally housed in a size 11 configuration. Designed for use with any Transicoil servo amplifier, the new device is also available with servo amplifier integrated in a slightly larger housing. Transicoil believes that the assembly provides remote transmission of angular positions, with accuracy and torque gradient better than any obtainable in available self-synchronous systems of this frame size. According to the company, the integrated design eliminates the bulky gear box platform and reduces cost considerably. Daystrom Inc., Transicoil Div., Worcester, Mass.

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"Tiniest" Transformers

What are believed to be the smallest three-phase transformers available today measure one by one by 17/32, for a total cubic volume of 0.53 cubic inches. Hermetrically sealed units are manufactured in accordance with Mil-T-27 A, Grade 5, Class R. Primary windings handle any voltage up to 200 volts at 400 cps; secondary windings produce any voltage up to 200 volts at 2 watts output. Titan Transformer Co., Cambridge, Mass.

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Magnetic Clutch

Fitted with steel housing and a nylon gear mounted on ball bearings, a miniature magnetic clutch, Model MC-541, is specifically designed for incorporation in multiple clutch-potentiometer assemblies. Coupling which converts clutch to an in-line drive is available. Unit is only 1" in dia and 1" long, has a minimum torque of 6 oz. inch, and when de-energized, exerts no drag on pot. Altair Research & Mfg. Co., Baldwin Park, Calif.

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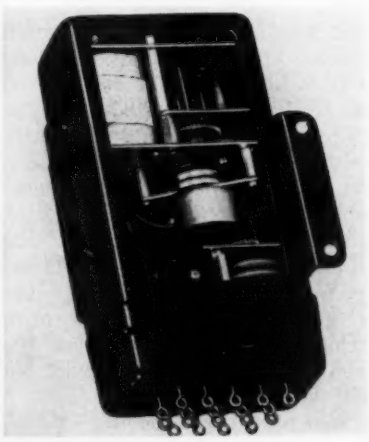

Miniature Time Delay Relay

Time range of time delay relay is from 15 seconds to 30 minutes or longer, with a repeat accuracy of 2% of overall time. Switches are fast make, fast break, SPDT, rated 3 amps resistive and inductive at 125 vac and 30 vdc, with a life of 50,000 operations minimum. Compactness (approximately 1" x 2" x 4") and light weight are achieved through use of newly designed 400-cycle (hysteresis) or 60-cycle (permanent magnet) 115v motors. Meets severe tests, including operation at 70,000 feet, vibration from 10 to 2000 cps at 10G's, and 50-G 11-ms shock. Cramer Div., Giannini Controls, Centerbrook, Conn.

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High Strength Adhesive

Substitution of a quick-setting adhesive, called Eastman 910, in place of more conventional mounting methods helps achieve greater miniaturization of electronic equipment. One particularly successful application involves the mounting of electrical relays to potentiometers. The relay cases are made of irodite-finished aluminum, and the potentiometer covers of phenolic plastic. One drop of the adhesive makes an almost instant bond between the two dissimilar materials. The Eastman 910 adhesive is said to be the first to produce quick-setting, high-strength bonds between virtually any combination of materials without the necessity of catalysts, heat, solvent-evaporation or more than contact pressure. Eastman Chemical Prod., Inc., N. Y., N. Y.

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Solid State Amplifier

Particularly applicable as a line driver or for driving high frequency galvanometers from the output of high impedance sources such as those associated with FM magnetic tape recording systems, a new dc amplifier is a single-ended, solid-state unit that offers frequency response to 10KC. Fixed gain steps of 1, 2, 5, and 10 with separate vernier control permits gain selection over the range of 1 to 20. Two outputs are provided for each channel: one input offers ¼ ohm output impedance for monitoring or line driver applications; the other output is taken from a plug-in galvanometer damping network internal to the amplifier. Delivery: 6 to 10 weeks. Price: $300 (without rack). Neff Instr. Corp., Duarte, Calif.

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Epoxy-Molded Resistors

Proprietary molding technique permits a new series of resistors to maintain precise stability without change in characteristics, even when subjected to thermal "plunge" shock tests from −60°F. to 365°F. According to the company, the technique permits a larger core size for a given wattage while retaining environmental characteristics far exceeding any other resistor encapsulation method. The epoxy-molded resistors, ranging from 1/10th watt to 1 watt, exceed all requirements of Mil-R-10509D, characteristics B, D, and F carbon film, typed and characteristics C and E for metal film units. Key Resistor Corp., 321 W. Redondo Beach Blvd., Gardena, Calif.

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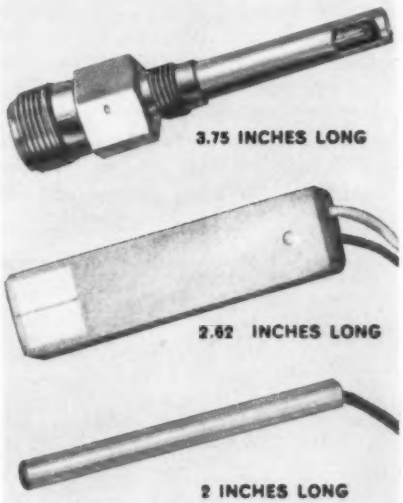

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NEW COMPONENTS

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Induction Motor

Continuous duty, high output-to-weight ratio induction motor, designed specifically to drive an axial vane blower, is thermally protected, enabling it to provide reliable service despite exposure to severe environments. This open-ventilated motor has air-over-motor cooling and it qualifies according to the applicable portions of MIL-M-7969 and MIL-E-5272. Horsepower: 15.5, power: 200 volts, 400 cps, 3 phase, speed: 11,600 rpm, weight: 19 lbs, 12 oz. Kearfott Div., General Precision, Inc., Little Falls, N. J.

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Reversible Synchronous Motor

Ac timing motor which has no slippage stops without coasting, and is instantaneously reversible without recourse to mechanical no-back devices. Consisting of permanent magnet rotor and electromagnetic stator with two coils with direction of operation depending upon the coil energized this synchronous motor delivers 30 ounce-inches of torque in either direction at 1 rpm and gives utmost precision in operation. No external breaks, quenching circuits, or phase shift networks are required. Weighing only eight ounces, the unit operates on 115 volt, 50 or 60 cps power supplies, and is offered in 150 different output speeds, ranging from 300 rpm to 1/6 rph and a choice of eight different output shafts. Designed initially for computer applications, the new motor has already found wide use in connection with printed circuitry, potentiometer drives, and related devices with sharply defined parameters. The motor is operable in temperatures ranging from −10°F to ±180°F. A. W. Haydon Co., Waterbury, Conn.

Write No. 435 in Box on Inquiry Card

Power Supplies

Noise-free family of power supplies features precise voltage regulation for both line and load. Six 60 cycle models are transistorized, miniature 115-volt a-c/d-c sine-wave inverters. Operating from 12 or 28-volt d-c inputs, outputs, obtained from Class B amplifier, range from 20, 40 to 60 watts. The units' net weights range from 2½ to 8 lbs. and can include tape motors, small magnetic amplifiers and gyros and similar equipment operating indirectly from batteries. Raytheon Co., Sorenson Prods., So. Norwalk, Conn.

Write No. 331 in Box on Inquiry Card

Top Hat Resistors

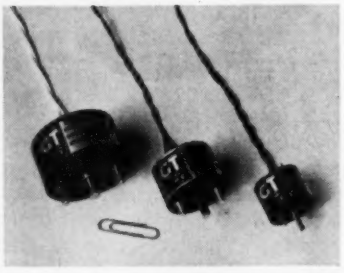
With fifty parts per million accuracy and long term stability of 0.003% per year, top hat encapsulated resistors, developed for the Polaris fire control system, are available over a 100 ohm to 1 megohm range of values. They bring high precision to printed circuits with ease of assembly and space saving advantages of single-end resistor construction. The models, 0.28″ in dia. and 0.40″ in dia., are 0.37″ long and can be constructed to specs with lower accuracies available at lower costs. Julie Research Laboratories, New York.

Write No. 313 in Box on Inquiry Card

Tape Recorder

Designed for recording flight test information on advanced missiles and space vehicles, multi-channel, miniature magnetic tape recorders record up to 14 channels of data simultaneously on 1" magnetic tape. Total tape capacity is 69'. Borg Warner Controls, Div. Borg-Warner Corp., Santa Ana, Calif.

Write No. 345 in Box on Inquiry Card



Rotary Solenoids Magnetically Balanced with Constant Torque

Withstanding severe shock, vibration, and thermal stresses during operational life of more than 1,000,000 cycles, newly developed rotary solenoids have a true rotary magnetic action with no axial motion of the shaft. Armature is balanced, both mechanically and magnetically, resulting in minimum thrust on the bearings. There is no unbalanced mass to be actuated by rapid acceleration or by shock. In addition, the armature is in a series air gap so that any reduction in air gap on one side automatically increases the air gap on the opposite side. Since both sides are in series, the resultant total series gap remains essentially constant. General Time Corp., Stamford, Conn.

Write No. 399 in Box on Inquiry Card

Double Pulse Generator

Providing a multiplicity of separate or mixed output signals, a precision double pulse generator features fast rise time and flexible modular construction. Accurate calibrated controls make it easy to set up reliable output parameters on the instrument itself. High power, accuracy to 0.5%, 0.02 microsecond rise time and repetition rate to 100 kc make the instrument applicable to a broad range of pulse simulation and control. Servo Corp. of America, Hicksville, N. Y.

Write No. 359 in Box on Inquiry Card

Hysteresis Clutch

Delivering controllable torque through a range of speeds and loads, new fractional hp hysteresis clutch is capable of synchronous driving or continuous slip with negligible torque variation at any slip differential. Essentially a power-dividing device with output torque proportional to dc control current, there is no connection in the unit between output and input shafts except the shaft support bearing. Residual torque at zero excitation is bearing friction only. Unit, rated at 1/20 hp, 1800 rpm, measures 2½" O.D., is applicable to business machines, tape tensioning devices, recorders and servo control systems. Scanner Corp. of America, Livonia, Mich.

Write No. 344 in Box on Inquiry Card

Airborne Magnetic Tape Recorder

Consisting of a precision tape transport coupled to an electronic module assembly, a 13 lb. airborne magnetic tape recorder records 14 tracks with laboratory precision in missile environments. Changing plug-in modules permit a choice of 14 tracks of wideband FM recording or 7 tracks of wideband FM and 7 tracks of direct recording. Magnetic heads with gaps of only 80 microinches help make possible high frequency response in relation to tape drive speed. Frequency response is dc to 10 KC in wideband FM and 50 to 100,000 cps in direct record at a tape speed of 30 ips. Tape packing density is 3300 cps. Westrex Recording Equipment Div., Litton Systems, Inc., Beverly Hills, Calif.

Write No. 340 in Box on Inquiry Card

Iterative Analog Computer

Designed with computing components matched to 0.01%, etched circuit wiring, pushbutton selectivity and modular packaging, Donner Scientific's iterative computer provides a wide dynamic range that assures precision in computing with amplifiers that exhibit only 20μ volts drift and 500μ noise. Unit contains a 0.05% solid state multiplier and stored program function generators housed behind 2" by 7" high modules which slide into the front of the computer. Because plug-in pot modules program the new function generator, association of several pot modules lets the user store functions simply and inexpensively. Reference potentiometer permits voltage measurement to 0.02%. Donner Scientific Div., Systron-Donner Corp., Concord, Calif.

Write No. 355 in Box on Inquiry Card

VĀP-AIR NI-CAD BATTERY CHARGER

Charger shown is for 19-cell 24 A.H. batteries. Other sizes are available . . . or Vāp-Air will design to your specific requirements.

- *no over-charge*
- *no under-charge*
- *longer battery life*

Especially developed for nickel-cadmium batteries in airborne or ground equipment. Pulse-charge operation prevents "trickle-charge." No excessive current during initial charge. Equalizes unbalanced cell conditions in battery. Automatically adjusts charge to compensate for high or low ambient temperature conditions, prevents over-charge or under-charge of battery.

BRIEF SPECIFICATIONS

Input Voltage.....200; 400 cycle; single phase
Ambient Temperature Range...54°C. to 71°C.
Altitude.....Sea Level to 50,000 Ft.
Continuous Current Charging Rate..25 amps DC
Maximum Current Rating.....50 amps DC
Efficiency at Rated Load.....80%
Approx. Weight.....11 lbs.

VĀP-AIR...COMPLETE CONTROL CAPABILITIES

Entire systems and a complete line of sensors, electronic controls and precise power supplies, electro-pneumatic and electro-mechanical valves, advanced in-line air valves and regulators, electric power controllers and heat exchange equipment—for aircraft, missiles, and ground support devices.

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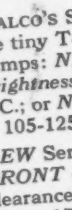
CIRCLE NO. 55 ON INQUIRY CARD

Sub-Min.

Widest selection of Pilot Lights –from DIALCO



T-2

NEON

HIGH BRIGHTNESS and REGULAR TYPES

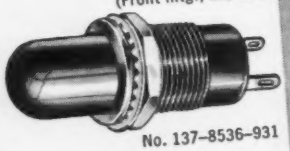
DIALCO's Sub-Miniatures use tiny T-2 Neon Glow Lamps: *NE-2J (High Brightness)* at 105-125 V., A.C.; or *NE-2D* (regular) at 105-125 V., A.C. or D.C.

NEW Series mounts from *FRONT* of panel in 15/32" clearance hole (supplements 17/32" Series). Also—units for mounting from *BACK* of panel in 15/32" clearance hole. Unique lenses in 5 colors; give all-angle visibility. Units are fully insulated; meet applicable Mil. Specs.

Ask for Brochures L-159C and L-160B.

(Illust. approx. actual size)

(Front mtg., 15/32")



No. 137–8536–931

(Front mtg., 17/32")

No. 145–5036–991

(Back mtg., 15/32")

No. 138–3836–1431–99

DIALCO®

T-1¾

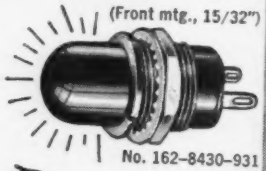
INCANDESCENT

2-TERMINAL and 1-TERMINAL TYPES

Designed for use with T-1¾ midget flanged incandescent lamps—1.3 V. to 28 V... *NEW* Series mounts from *FRONT* of panel in 15/32" clearance hole—(supplements 17/32" Series). Also—units for mounting from *BACK* of panel in 15/32" clearance hole. Unique lenses in 7 colors. Units are fully insulated; meet applicable Mil. Specs.

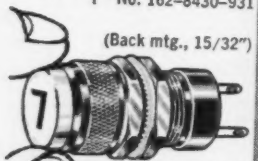
Ask for Brochures L-156D thru L-159C.

(Front mtg., 15/32")



No. 162–8430–931

(Back mtg., 15/32")



No. 134–3830–375–7

Spring-mounted Lens-with-Message is *rotatable.*

1-Terminal Pilot Lights

For use on *grounded circuits.* Mount in 13/32" or 15/32" clearance hole. Binding screw or soldering terminal.

(Front mtg., 13/32")

No. 101–4630–971

SAMPLES ON REQUEST—AT ONCE—NO CHARGE

Foremost Manufacturer of Pilot Lights

DIALIGHT CORPORATION

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CIRCLE NO. 56 ON INQUIRY CARD

NOW... A SIX SPEED INSTRUMENT GEAR MOTOR

ALLOWS DIAL SPEED SELECTION WHILE RUNNING.

Here is a new, versatile instrument gear motor with six output speeds, any of which can be quickly and easily changed by operator while motor is running. It is furnished with positive, exactly repeatable ratios of 1:1, 2:1, 5:1, 10:1, 20:1 and 50:1. A variety of basic synchronous motor speeds is available. The unit is built to standard NEMA Size 25 Frame.

This dependable, compact gear motor can be used as a new instrument component for prototype testing or in breadboards where its adjustable speed feature will give better, faster results.

CHART DRIVES • SPEED REDUCTORS • INSTRUMENT DRIVE SYSTEMS

INSCO COMPANY

DIVISION OF BARRY WRIGHT CORP. BW

GROTON, MASSACHUSETTS

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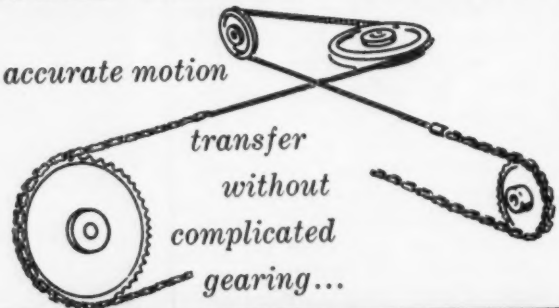
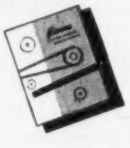
MORE DESIGN FREEDOM



SIERRA MINIATURE MECHANICAL CHAIN AND SPROCKETS...

Provide precise, positive motion transfer through several planes simultaneously with no cable slippage...no complicated gearing. Unlimited center-to-center selection for miniature and sub-miniature assemblies in servo systems, gyro systems, special cameras, electronic equipment, and small precision instruments. Less weight, cost, maintenance —wider tolerances. Designed to operate around minimum 7-tooth sprocket with root diameter of .250 inches. Chain pitch .1475 inches; Weight .45 oz. per lineal ft. Material: stainless steel, or other materials.

NEW CATALOG



Contains useful application data, specifications, tables on chain pitch and sprocket sizes, suggestions for calculating center-to-center distance. *Write for yours today*

SIERRA ENGINEERING CO.

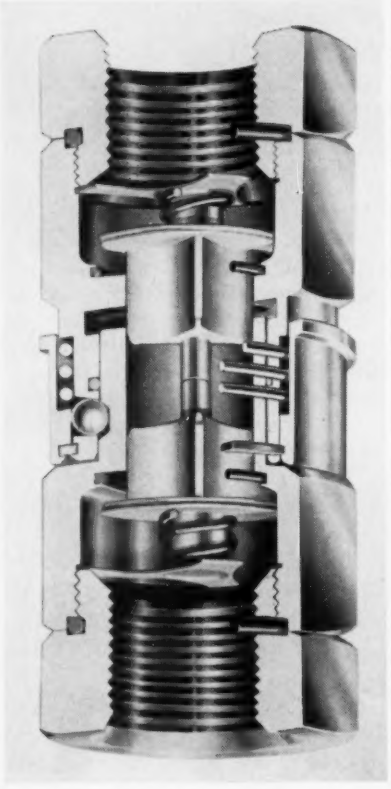
123 E. Montecito Sierra Madre, Calif.

CIRCLE NO. 78 ON INQUIRY CARD

Magnetic Heads

Multichannel heads provide for simultaneous recording of up to 20 channels per inch on tape or drum. Units are available in six compatible track formats with track widths from 0.200 to 0.050″ and track spacings from 0.050 to 0.140″. A co-linearity of leading and/or trailing edges of gaps to ±0.000050″ within head stack assures timing accuracy of recorded information between channels. Brush Instruments, Cleveland, Ohio.

Write No. 374 in Box on Inquiry Card



Quick-Connect Couplings

The spray which occurs when connecting or disconnecting a valved coupler-plain nipple combination has been eliminated by a new series of couplings. The "ES" series utilizes a positive metal-to-metal stop when the valve is in the closed position. This controls the compression and displacement of the valve seal. An extra O-ring seal in the coupler, in addition to the E-packer seal, prevents spray when there is internal pressure on one side of the coupling. The couplers are designed for high pressure, low pressure, gravity flow and vacuum systems and are available in two types with both nipple and coupler valved for double shutoff or with valved coupler and plain nipple for single shutoff. Snap-Tite, Inc., Union City, Pa.

Write No. 315 in Box on Inquiry Card

Self Aligning Locknut

With the seating surface as much as 8° out of perpendicular to the shank, a fastener still develops full rated strength of 160,000 psi. The compensating fastener consists of a hex drive featherweight self-locking nut which swivels within the spherical seal of a precision alignment washer. Design enables fastening strength to be utilized at all angles. Standard Pressed Steel Co., Jenkintown, Pa.

Write No. 348 in Box on Inquiry Card

Commutating Switches

Commutating, programming and sampling switches range from sealed subminiature modules for missile applications to rack mounting for ground support and industrial use. They are motor driven at speeds up to 3600 rpm but can also be coupled to stepping motors, timing motors or manual drives. Precious metal brushes transmit signals to associated equipment. Rotary Devices Corp., Englewood, N. J.

Write No. 406 in Box on Inquiry Card

Quick-Connect Terminal Resistors

Quick-connect terminals requiring no solder are now available on power wirewound resistors. They reduce assembly time and permit disconnecting of leads with equal speed to simplify field service. Quick-connect terminals are available on all resistor sizes from 5 to 200 watts. P. R. Mallory & Co., Inc., Indianapolis 6, Ind.

Write No. 394 in Box on Inquiry Card

High Torque DC Motor

Capable of sustained output torques of about 40 oz-in at 2 rpm, an instrument type dc motor delivers the high output torque at a low power input level of 180 mw. average. Motor measures 2-19/64″ x 2-1/8″ x 1-9/16″ and weighs 3 oz complete with reduction gear. Brailsford & Co., Inc., Rye, N. Y.

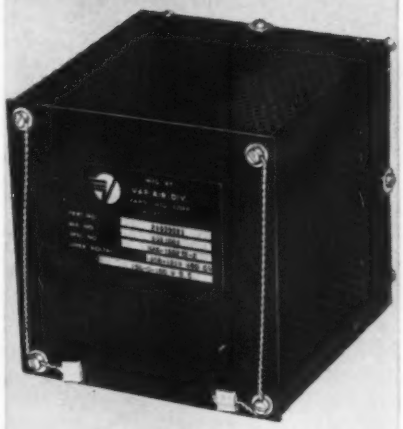
Write No. 347 in Box on Inquiry Card

Miniature Thin Resistors

With core thickness of ⅛″ and lengths ¾″ (10-watt unit), wirebound, vitreous enameled resistors are available in 10-15-and 20-watt sizes. Mounting brackets on the miniature units distribute heat evenly thereby minimizing hot spots, and conducts heat directly to the chassis surface. Ohmite Mfg. Co., Skokie, Ill.

Write No. 434 in Box on Inquiry Card

VĀP-AIR POWER SUPPLY



Other models and sizes available . . . or, Vāp-Air will design to your specific requirements

with regulation accuracy ±.5%

This compact dual function constant voltage regulator is used in a radar analyzer application. It provides stable outputs of −150 VDC and +150 VDC from an input of 115 VAC. Small, lightweight, accurate. Provides close voltage regulation over wide temperature range. Uses solid state techniques for high reliability, optimum performance.

BRIEF SPECIFICATIONS

Input Voltage...	108 to 121 VAC, 400 ±20 CPS, Single Phase
Output Voltage..... (under all input, load & temperature conditions)	+150 VDC ±.5% and −150 VDC ±.5%
Load	0 to 150 MA
Output Ripple	
Normal Operation	Zero
Transient Condition	.50 MV peak to peak
Temperature Range	−65° to +180° F.
Size	4″ x 4″ x 4″
Weight	4 lbs.
Environmental	MIL-E-4970A

VĀP-AIR... COMPLETE CONTROL CAPABILITIES

Entire systems and a complete line of thermal sensors, electronic controls and precise voltage regulators, electropneumatic and electromechanical valves, advanced in-line valves and regulators, electric power controllers and heat exchange equipment—for the aircraft, missiles, ground support and electronic industries.

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CIRCLE NO. 58 ON INQUIRY CARD

NEW COMPONENTS

10-Turn Precision Pot

Bourns, Inc., of Riverside, Calif. has entered the field of precision muliturn potentiometers with a 1" long, 10-turn unit that offers 20% longer resistance element in a case ⅞" dia. by 1" long. Designated Model 3500, Bourns guarantees model to meet cycling humidity specs and claims it to be only product of its type that will do so. Prices range from under $10.00 on average quantities with a 10% premium on cycling humidity performance.

Write No. 341 in Box on Inquiry Card

Cavity Antenna

8-oz. S-Band Cavity Antenna operates over the frequency range from .75 to 2.95 Gc and has a VSWR of less than 1.65 at continuous temperatures of up to 250°F. Radiation patterns are similar to those of a monopole. Antenna has RF choke which insures electrical continuity across mounting surface and enhances pattern characteristics. Foam filling and fiberglas covering eliminates moisture entrapment and meets MIL-E-5272C. Input connector is a TNC female with other input connectors available. Canoga Electron. Corp., Van Nuys, Calif.

Write No. 346 in Box on Inquiry Card

Miniature Pulse Transformers

Epoxy transfer-molded miniature pulse transformers, with oriented-grain silicon steel ribbon core units, ferrite torroid and ferrite cup cores, are available in four basic case styles plus a variety of custom shapes. Transfer-molded of epoxy under 1000 psi at 300°F, cases are accurate of shape to within 10 mils. High epoxy density eliminates pores and increases performance uniformity, resistance to chemical attack and aging; the epoxy also provides positive bonds to leads and prevents contamination of interior. Pulse Engineering Inc., Santa Clara, Calif.

Write No. 317 in Box on Inquiry Card

Heat Sink Kit

Design and packaging engineers can now purchase a kit containing 17 natural convection, conduction and forced convection-including fan – with 3 sets of mountings and a supply of interface grease for $37.50. Kit covers all possible transistor applications; and includes manual aids in proper selections. Astro Dynamics, Inc., Burlington, Mass.

Write No. 343 in Box on Inquiry Card

Transistor Plate Capacitor

With a square configuration which affords improved reliability and temperature capacitance characteristics at no increase in cost over the conventional round configuration, transistor plate capacitors have a capacity range from 0.005 mfd to 0.1 mfd and come in sizes from 0.280" sq. to 0.700" sq., with a 50 VDC working voltage. The coating is a durez phenolic, wax impregnation. Hi-Q Div., Aerovox Corp., Myrtle Beach, So. Carolina.

Write No. 362 in Box on Inquiry Card

20 Sec. Angle Repeater

Using the electrical output from synchros, resolvers or function generators, Theta Instrument Corp.'s Precise Position Repeater provides both a visual readout and binary coded data output of the angular position with 20 sec.-of-arc accuracy and 4 sec.-of-arc resolution. The Saddle Brook, N.J. company uses a solid state, self-stepping circuit. Unit tracks rotating systems with full accuracy in either direction; only operator control is an on-off switch.

Write No. 353 in Box on Inquiry Card

FOR MORE RELIABILITY RESISTANCE POWER

SPECIFY CON-ELCO®

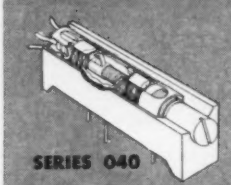
FOR CIRCUIT TRIMMING BALANCING CALIBRATION

ALL CON-ELCO TRIMMING POTENTIOMETERS AND VARIABLE RESISTORS FEATURE RELIABILITY AND ACCURACY PREVIOUSLY UNAVAILABLE TO INDUSTRY FOR CIRCUIT TRIMMING, BALANCING AND CALIBRATION.

TYPICAL SPECIFICATIONS

Power Rating: 1w, 2w and 2¾ @ 50°C derate to 0 at 105°C, 150°C and 180°C
Temperature Range: —55°C to +105°C and 180°C
Resistance Range: 10 to 125,000 ohms
Humidity Seal: Mil-E-5272 Proc I and Mil-Std-202 Method 106
Terminals: Terminal configurations available include printed circuit pins, solder lugs and flexible leads.
Case: Several units are available in single or multiple unit rectangular cases.

CON-ELCO standard models are available from stock. Let CON-ELCO engineers help you with your application problems. Send for data today.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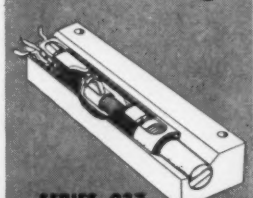
SERIES 023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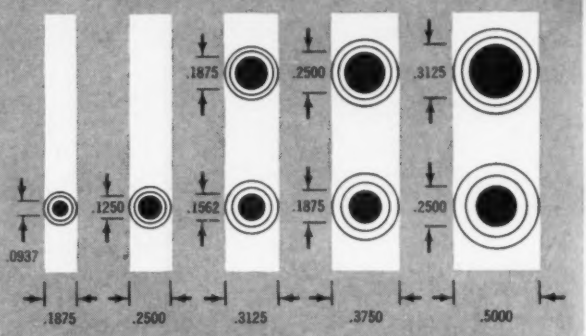

MORE SHAFT PER HOUSING

These New Hampshire miniature instrument bearings have extra-large bores which permit you to increase shaft diameters without increasing bearing O.D. — to add strength yet keep center distances at a minimum. Available as plain, flanged, double shielded or extended inner ring bearings or in any combination of the latter three constructions. Precision standard is ABEC Class 7.

NEW HAMPSHIRE BALL BEARINGS, INC. PETERBOROUGH, N. H.

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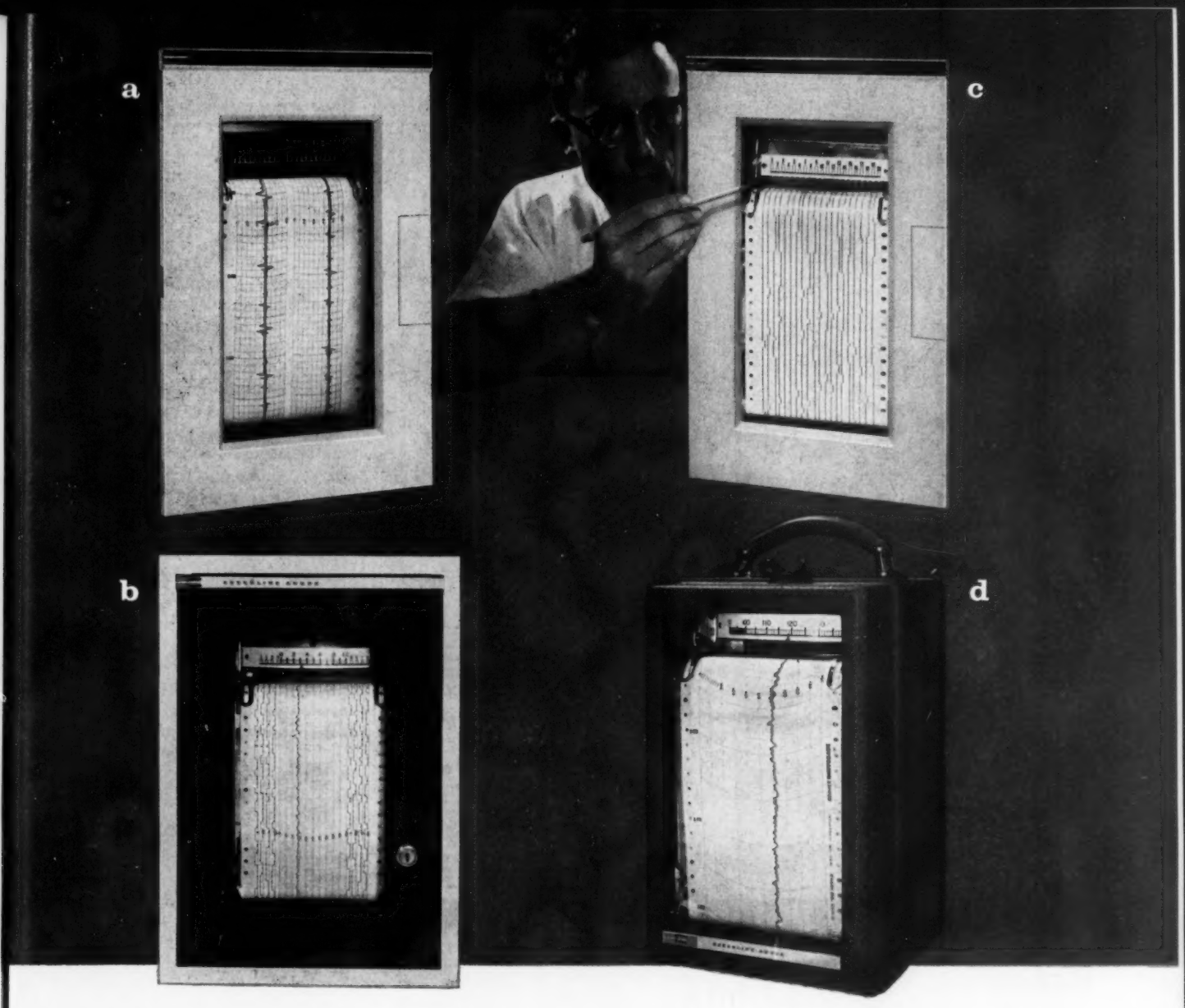

Available in portable, wall, flush and projection mounting switchboard cases.

NEW Instrument Designs, Applications from Esterline Angus

a New "602" Two-channel Recorder • Simultaneously records two variants on adjacent ½"-sections of single 6"-wide chart. Applications: checking current and voltage, quality determination of arc welds, records of input vs. output.

b New Analog-Event Recorder • One instrument does the work of two . . . simultaneously records analog data and up to 8 channels of event information on single 6"-wide chart. Applications: wind speed and direction, substation bus voltage and breaker operation, rate of production (speed) and conveyor operation.

c New "620" Event Recorder with Tempen • Writes without ink, using electrically-heated styluses. Simultaneously records "when," "how long" and "how many" on as many as 20 channels. Applications: productive and non-productive time of any or all machines in a plant, circuit breaker action, qualitative analysis, missile performance.

d New Expanded Scale Voltmeter • Provides increased readability of voltage records as upper ¼ of voltage range is expanded to fill upper 80% of chart span. Applications: checking voltage regulation, voltage records, trouble-shooting.

Standing solidly behind the creative designs of our engineering staff are the highly-developed skill and attention to detail of our master craftsmen. At right, M. R. Felske, Master Craftsman at Esterline Angus for 34 years. *For more detailed information on any instrument or its applications, write:* ESTERLINE ANGUS INSTRUMENT COMPANY, INC., Box 596-K, Indianapolis 6, Indiana.

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For the Pulse Forming Networks that meet critical Mil. Specs., for environmental conditions . . . specify Plastic Capacitors . . . the name of proved reliability in plastic film dielectric units. These superior units have a range in standard design from 0.1 microseconds up. Operation up to 125°C. Designed to match any impedance. Here is "on the job" performance you can count on. Special applications invited.

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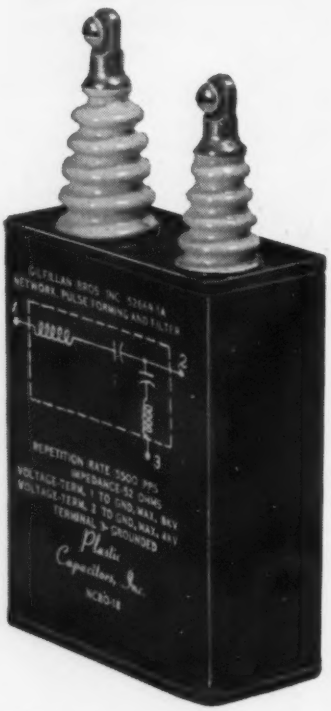

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Custom Engineering at Production Prices

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WITH

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LOW-LEVEL MAGNETIC AMPLIFIERS

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CIRCLE NO. 62 ON INQUIRY CARD

NEW COMPONENTS

Printed Circuit Trimmers

Two new trimming potentiometers, in square configuration, with base pins for printed circuit application, are ⅜" and ½" square respectively. Units feature humidity proof construction in compliance to MIL-STD-202A, Method 104, Condition A and MIL-E-5272C, Procedure 1. Rectangular cross-section resistance element has greater surface contact with case providing better heat dissipation. Dual wiper design guarantees positive contact under all conditions of shock and vibration. 25-turn units meet or exceed all applicable military specs. Spectrol Electronics Corp., San Gabriel, Calif.

Write No. 337 in Box on Inquiry Card

Size 9 AC Potentiometer

Size 9 low-cost "Vernistat" ac potentiometer has an extremely high input to output impedance ratio, high terminal linearity, low phase shift and a high inherent reliability. The Vernistat achieves precise voltage ratios and low output impedance by means of a tapped autotransformer; tap voltages do not change with time, use or environment. High precision pot interpolates between the autotransformer voltages permitting use of a larger potentiometer wire for a given resolution and input impedance than with conventional units. Low output impedance allows for elimination of isolation amplifiers. Perkin-Elmer Corp., Norwalk, Conn.

Write No. 326 in Box on Inquiry Card

Wire Wound Resistors

Specially developed coating, thermally conductive and electrically insulating, insures complete protection against salt spray, vibration and mechanical and thermal shock in a new line of precision, wire-wound standard resistors. For added built-in reliability these resistors have end-to-end welded construction. They operate at twice full rated power for extended periods of time and withstand ambient temperatures to 350°C. Power: 2 to 10 watts. Resistance range: 1 to 175K ohms. Standard tolerances: 1 to ±20%. Dielectric strength: 1000V. Temperature coefficient: 0.00002/°C. Resistors allow exceptionally high heat dissipation. RECO, San Gabriel, Calif.

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Precision Potentiometers

For use where small increments of shaft rotation must produce proportionally small changes in resistance, a deposited film precision potentiometer provides resolution of better than 0.01%. Unit measures but 1 1/16" in dia. The resistance element is manufactured in a high vacuum chamber using electron bombardment techniques. This method provides a thin film metallic resistance element of extremely fine granularity capable of being resolved into infinitesimally small changes in resistance. The potentiometer is the result of over 6 years of development and marks company entry into field. Mechatrol, Westbury, N. Y.

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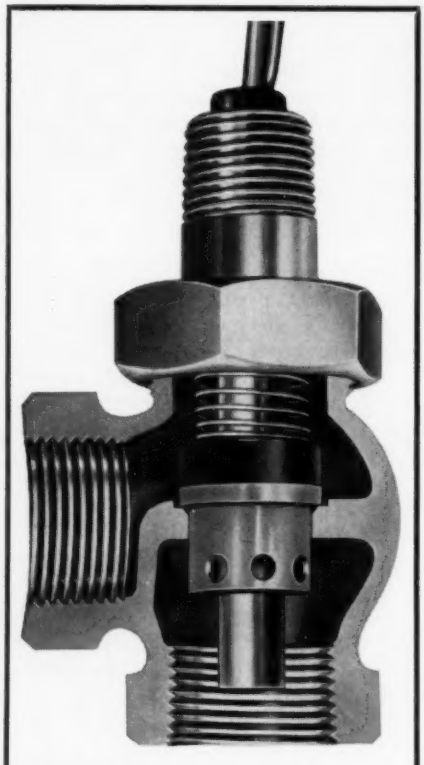

Flow Switch

Compact and simple in design, a low-cost flow switch detects variations in the flow rate of fluids or gases for a positive indication. Unit may operate a remotely located warning light or other indicator, visual or audio. Automatic interlocks or pump motors may be actuated through relays. Displacement of the magnet-equipped shuttle by a fluid or gas actuates the hermetically sealed switch contacts within the bronze stem. Bypass holes in the shuttle skirt permit maximum flow with a minimum pressure drop. Dependable and precise in repeatability, the unit is said to be low enough in cost for economical large-system quantity usage. Gems Co., Inc., Farmington, Conn.

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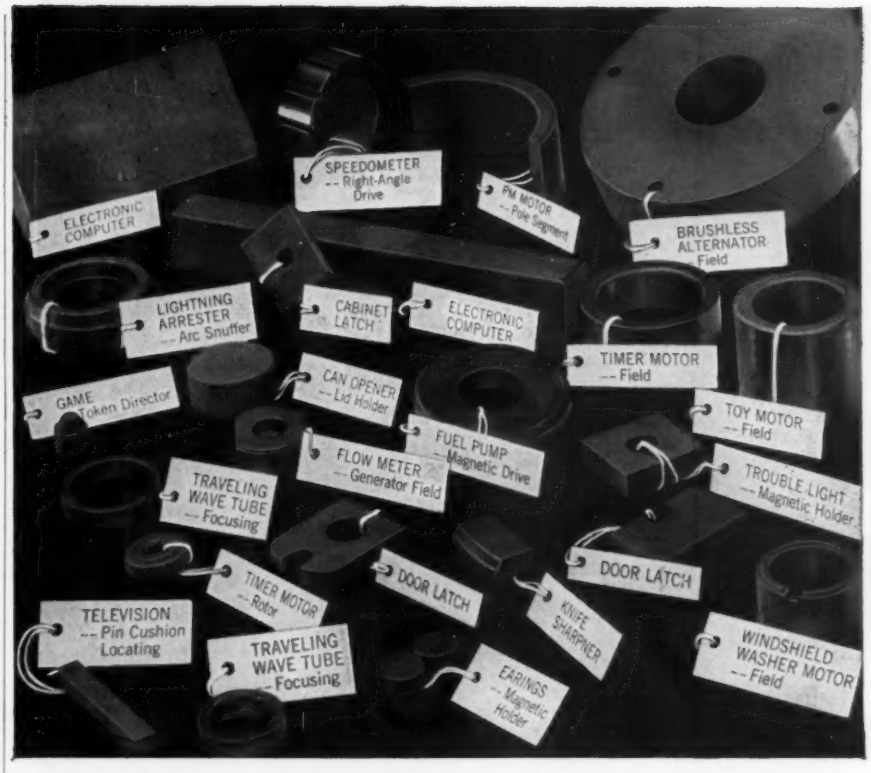

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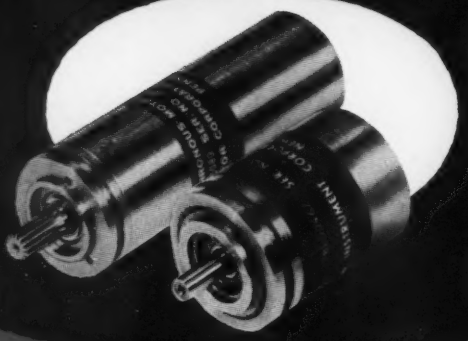
CIRCLE NO. 81 ON INQUIRY CARD

new size 8



synchronous motors

(Geared or Ungeared in ¾" dia.)

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CIRCLE NO. 64 ON INQUIRY CARD

NEW COMPONENTS

Cerafil Capacitors

For sandwich-type circuit construction and where component length and/or diameter are highly critical, special ¼"-long Cerafil capacitors in 10-1000 mmfd capacities are made in lacquer coated, Durez coated or epoxy molded cases, depending on diameter and/or test requirements. Lacquer coated units are the smallest and are primarily intended for potted circuit applications. Units can be made as high as a 100 vdc rating. Capacity tolerance as low as 7½% can also be achieved. Durez and molded units meet all Mil-C-11015B requirements when tested using Cerafil ratings. Hi-Q Div., Aerovox Corp., Olean, N. Y.

Write No. 322 in Box on Inquiry Card

Thermal Switch

New thermal sensing device solves drift problems due to life, vibration and shock or temperature overshoots or undershoots. This new bimetal sensing switch is hermetically sealed, highly sensitive and extremely accurate. It has a calibration range of −20°F to 600°F. Repeatability is approximately ±1°F. The switch is extremely flat – measuring just ¼" in thickness – and is ¾" wide by 1-9/32" long, including leads, and weighs 0.9 oz. The device complies with MIL-E-5272A – Procedure I regarding environmental, shock, and vibration requirements. Control Prods., Inc., East Hanover, N. J.

Write No. 325 in Box on Inquiry Card

Instrument Bearings

Thin cross sections of new bearings permit never-before design options, according to manufacturer. For applications requiring combinations of bearing dimensions "in-between" dimensions of standard instrument bearings, the new series contain extra-large bore-to-OD ratios. With material of 44OC stainless steel and retainers of plastic crown design with lubricant absorption properties, the bearings are manufactured to ABEC Class 5 and better precision standards. Bore/OD combinations include: 0.3750", 10.6250", 0.50000", 10.7500", 0.6250", 10.8750", 0.7500"/1.000". Widths are standard at 0.1562". New Hampshire Ball Bearings, Inc., Peterborough, N. H.

Write No. 311 in Box on Inquiry Card

CONTRACTS

"It disappeared into thin air." Or to be more exact, "into no air at all." Metal evaporation studies at Hughes Aircraft Co. show that whole sections of a space vehicle might "disappear" during an extended space voyage if the wrong metal is used in its construction (This might present a rather sticky problem to the pilot). Experiments on a "vacuum train" fabricated at Hughes have brought to light a host of new and perplexing problems with which engineers will have to contend when designing equipment to operate in space. Some specific problems being studied are:

- Grease and other lubricants vaporize in ultra-high vacuum.
- "Cold welding" of metals in contact with each other becomes a fact in a matter of days in absence of air.
- Some tough plastics, such as vinyl, grow brittle and lose strength due to evaporation of their plasticizer. In other cases, high vacuum "protects" plastics. Teflon, for example, was found to be an excellent material to use in space.
- Microorganisms die if exposed to ultra-high vacuum for periods of 20 to 30 days, indicating that the costly practice of sterilizing the exterior of spacecraft prior to launch to avoid contaminating other planets may not be necessary. These findings also argue against the theory that life may have been brought to earth in the form of free-floating spores from outer space.

Studies are part of a space environment research program under way in the components and materials laboratory of the Hughes aerospace group. The metal evaporation problem, although in need of much further study, does not appear to be insoluble, according to Charles G. Walance, manager of the laboratory. It was found that certain anodic coatings reduce evaporation rates by as much as 70 times; gold plating also was found to be effective. Metals most susceptible to evaporation were found to be cadmium, zinc and certain magnesium alloys. As expected, heat increased the rate of evaporation in high vacuum just as it does in atmosphere. Iron and steel were found to be highly resistant and would last for years in space. Titanium, tungsten and platinum are among the best materials.

To prevent seizure in space, a lubricating film must be maintained on bearing surfaces throughout the service life of the space vehicle, Walance said. Preventative techniques which show promise include: using low vapor pressure greases so that evaporation is slow enough to maintain a lubricating film during the required period of time; constructing bearings of such materials as Teflon which do not require a lubricant and will not seize; utilizing solid film lubricants such as MoS_2; maintaining pressure at the surface of the bearing metal above 10^{-6} mm Hg and temperatures below 100°C.

The "Bottom Bounce", which sounds like a new dance craze, is actually a method used in an advanced navigation aid for submerged submarines. Under a $99,000 contract from the Navy's Bureau of Ships, the Electronics Division of Martin Co. at Baltimore will study both passive and active submarine navigation aids. Findings to date, John J. Slattery, Gen. Mgr. reported, suggest that the best navigation aid may use a "bottom-bounce" method of projecting underwater sound. With this method, sound is projected obliquely toward the ocean floor, where it bounces back to the surface and then falls back again to the ocean floor. This "bounce" effect may occur several times, depending on depth of the water, temperature, and characteristics of the ocean floor. Direct acoustic propagation will also be investigated.

With a capacity of 500 pounds, an advanced air bearing turntable promises to be the largest precision air bearing unit ever made, according to Joseph M. Dunn, president of Dunn Engineering Corp., Cambridge, Mass. NASA has awarded the company a contract for a turntable that will evaluate the equipment guiding Saturn. Literally floating on a thin film of air while spinning, with essentially no friction, Dunn's turntables are used to check out the accuracy of components and complete inertial guidance packages. Specs called for under the new contract include: turntable axis runout, ±1 arc second; turntable face runout, ±3 arc seconds; axis orthogonality, ±3 arc seconds. The turntable will be capable of rate and servo mode operations.

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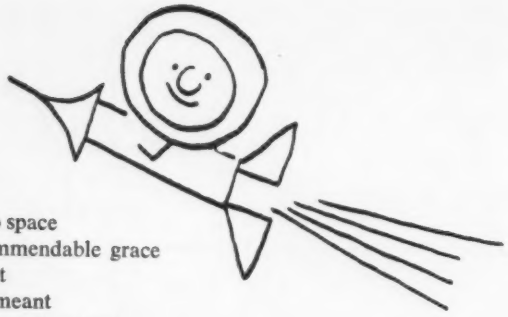

A rocket shot off into space
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BOOK REVIEWS

Nondestructive Testing

Warren J. McGonnagle,
Associate Physicist,
Argonne National Laboratory
457 pages, $15.00
McGraw-Hill Publishing Co.
327 West 41st St., New York 36, N.Y.

Physical principles, techniques, advantages, and limitations of the various methods of nondestructive testing are covered comprehensively. Based on applied physics, the treatment in the book stresses nondestructive testing as a science and outlines the what, how, when, and where of this rapidly-developing technology. The author points out that this type of testing is concerned not only with the detection and location of flaws in material, but that its methods and techniques measure physical properties or nonuniformities in the physical properties of specific materials. Among the major testing procedures treated in detail are visual testing, pressure and leak testing, liquid penetrant inspection, thermal methods, X-ray and gamma radiography, ultrasonics, dynamic testing, magnetic, electric and eddy current methods.

Flow Meter Handbook

Charles F. Cusick
170 pages, $7.50
Brown Instruments Div.
Mail Station 0280
Minneapolis-Honeywell Regulator Co.
Wayne & Windrim Aves.
Phila. 44, Pa.

A new edition of its Flow Meter Engineering Handbook has been published by the Brown Instruments Div. of Minneapolis-Honeywell Regulator Co. First issued in 1936 and then revised in 1946, the new handbook contains basic flow calculations rearranged for easy reference and includes primary measuring devices other than orifice plates. Included are many schematic diagrams, graphs, charts, tables. Separate chapters cover steam, liquid and gas flow calculations, each with all the data necessary to calculate or check an orifice plate installation. Three solutions to a flow problem are outlined in each chapter: an approximation check, a nominal orifice bore calculation and a precise orifice bore calculation.

For Your Literature File
NEW CATALOGS

Most of these catalogs contain complete specs, mounting configurations and other important details associated with the application of the products described. For your free copy of the catalogs listed on this page, enter the appropriate number of the item on the Inquiry Card.

Fastening Devices 957

Summarizing the various classes of spring-tension fasteners, brochure covers customized designs for clamps, clips, latches and locks, pins, retainers, snap rings, hooks and holders, catches, spring washers, hangers, and collars. Case-history examples demonstrate how spring-like flat stampings can simplify design, cut costs, and improve reliability. (4 pp). Associated Spring Corp., Bristol, Conn.

Power Supplies 976

Combining a switching pre-regulator with a series regulator, a new power supply design achieves a transient response of 50 microsec in 80% efficient watts delivering up to 1080 watts. Other advantages include: package size reduction; instantaneous electronic protective system which automatically adjusts for shorts and overloads with no increase in internal power dissipation; reliability and reduction in system cooling requirements. (4 pp). Valor Instruments, Inc., Gardena, Calif.

Germanium NPN Transistor 987

High speed computer switching transistor which meets Mil-S-19500B requirements combines high current gain, high frequency performance, low collector capacitance and low leakage current with a high emitter breakdown voltage. Two pages of a brochure are devoted to a characterization by the charge control switching concept which provides a precise prediction of switching speed over a wide range of collector voltage and current. Bulletin also includes charts on major characteristics. (6 pp). General Electric Co., Semiconductor Prod. Dept., Liverpool, N. Y.

Thermocouple Reference Junctions 994

Titled "Thermo-Ref Thermocouple Reference Junction," booklet details thermocouple materials used, specifications and operating characteristics. It also includes useful information on general principles and applications. (10 pp). Genistron, Inc., Los Angeles, Calif.

Transistor-Diode Heat Radiators 956

Details of more than 72 semiconductor radiators are listed for most TO case outlines. Comprehensive discussion on thermal cooling covers semiconductor installation, formulae on thermal runaway, transistor derating curve and formulae, thermal/electrical analog, and formulae of heat dissipation by radiation, convection and conduction. Four laboratory test reports show how these radiators increase semiconductor efficiency up to 27 percent and prevent thermal runaway. The Birtcher Corp., Monterey Park, Calif.

Carbon-Graphite Materials 960

Bulletin tabulates 18 grades of carbon, graphite, and carbon-graphite for such uses as bearings, bushings, and seals and lists properties for each grade. Recommendations are given for seals and sliding surfaces for a wide range of liquids and gases at operating temperatures up to and above 500°F., and in the cryogenic range. Discussions on carbon-graphite materials' high elastic modulus, total impermeability, maintained flatness, resistance to chemical attack, thermal conductivity, and low friction and wear are included. (8 pp). National Carbon Co., New York, N. Y.

Low Power Tubes 978

Handbook, covering low-power transmitting tubes, series regulators, rectifiers and clipper tubes, charts all specifications and diagrams each tube's base and envelope connections. (6 pp). Raytheon Co., Newton, Mass.

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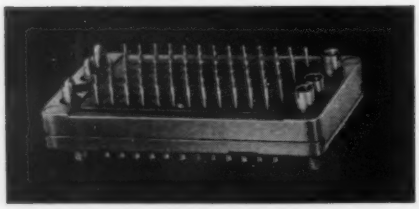

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NEW CATALOGS

Variable Resistors 979

Brochure on 6 types of linear motion variable resistors contains dimensional drawings of encapsulated and non-encapsulated units. In addition to general electrical specs, detailed information is given on mechanical and environmental inspection and test specifications. (4 pp). Centralab, Milwaukee, Wis.

SCR Capacitors 699

Capacitors for silicon controlled rectifier applications are rated at 0.1 to 60 mfd and up to 4000 v rms. Bulletin discusses the parameters and other characteristics that should be considered when selecting capacitors. A handy table lists for each application, the capacitor type to be used and the criteria for its selection. (4 pp) G. E. Co., Schenectady, N. Y.

Electric Motor Components 983

Catalog lists molded brush retaining caps, carbon brush holders, commutators, and slip rings, available from stock dies with optional insulating materials and engineering variations. Midwest Molding & Mfg. Co., Gurnee, Ill.

Analog Computer 950

100 amplifier general purpose analog computer has basic building block design which allows easy expansion. Booklet describes the many automatic features and available readout equipment. (20 pp). Electronic Associates, Inc., Long Branch, N.J.

Single-Turn Wirewound Pots 660

Illustrated brochure, describing linear, nonlinear and sine-cosine precision pots, contains performance data on 11 models and explanatory section describing special features. (6 pp) Fairchild Controls Corp., Hicksville, N. Y.

Constant-Current Power Supply 668

Eleven models in a rapidly expanding series of constant-current dc power supplies are now available in ranges up to 1 amp. Brochure, describing widening spectrum of applications, contains definitions of parameters as they differ from those of voltage-regulated power supplies. Electronic Measurements Co., Inc., Eatontown, N. J.

Modular Thermal Blocks 658

Designed to replace barrier and terminal boards presently in use in switchboards, control panels, industrial instrumentation, and other applications where maximum distribution of control and versatile power control circuiting are essential, Termi-Blok, a new modular, terminal panel wiring block, is described as having the following advantages over traditional boards; extremely high density per lineal inch of track; versatility in circuitry stack configurations; tool-free insertion, withdrawal and changing of circuit leads. (4pp) Amp, Inc., Harrisburg, Pa.

Dry Type Transformers 981

Extensive line of single phase, three phase and phase changer dry type transformers are covered in what is described to be the most complete and comprehensive catalog published on this type of transformer. Wiring diagrams, specs and prices are included. (36 pp) Atlantic Transformer Co., Phila. Pa.

Digital Multimeter 977

High-speed, solid-state, analog-to-digital converter and multifunction signal conditioning unit is fully transistorized and designed to meet the rigorous environmental requirements of military specifications. Available in either 3 or 4 digit binary-coded decimal outputs, unit has applications in automatic checkout systems, process monitoring, and automatic test sets. (4 pp) Epsco, Cambridge, Mass.

Motors 953

Maximum performance for a wide range of load requirements is possible due to the advanced design of right-angle worm gear motors. Brochure describing units lists ratings and dimensional data for both single reduction and double reduction types. (4 pp). U.S. Electrical Motors Inc., Los Angeles, Calif.

Stock Transformers 958

Catalog lists complete standard line of high reliability transformers, toroids and subminiature toroids. Separate section describes custom design service on transformers, magnetic amplifiers, filters and other components. (28 pp) Arco Electronics, Great Neck, N. Y.

Teflon Terminals 989

Listed in catalog are "Press-Fit" terminals such as subminiature stand-offs and feed-throughs, probes and plugs, miniature stand-offs and feed-throughs, connectors and test jacks. In addition, insertion tools for installation are described. Sealectro Corp., Mamaroneck, N.Y.

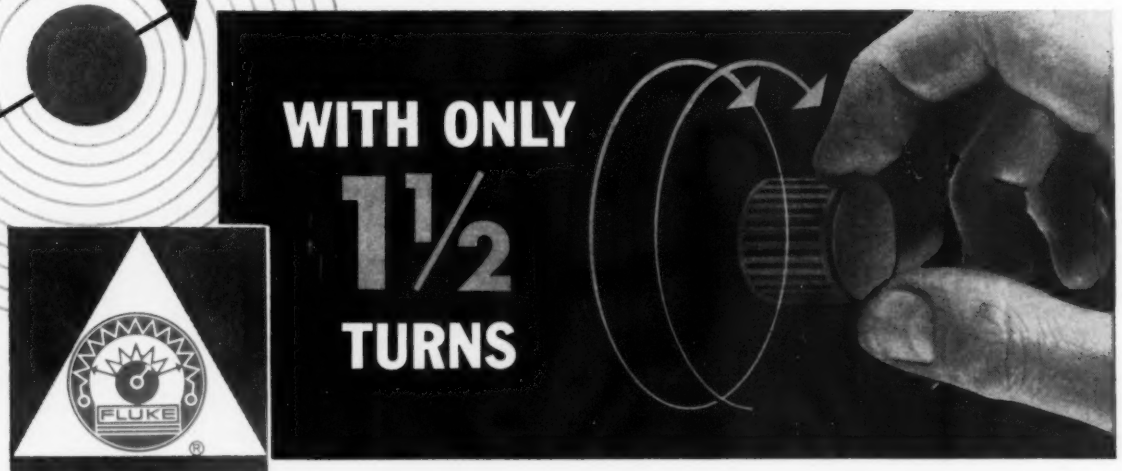
Precision Switches 962

Descriptions of over 200 items include miniature switches, special purpose switches, electronic switch-circuit assemblies, lighted pushbutton, toggle, limit, proximity and mercury switches. (20 pp). Micro Switch, Div. Minneapolis Honeywell Reg. Co., Freeport, Ill.

Sequence Timer 657

Motor-driven sequence timer is built around a micro-adjustable cam. The assembly consists of a housing locked to the drive shaft by a set screw, with the cam and drive gear unit free to rotate inside the housing around the shaft. Adjusting screw engages the cam's drive gear. When the screw is rotated it turns the cam at a 40 to 1 ratio. It is self-locking; and, after the cam is positioned, no further adjustment is needed. Event sequences are adjustable to within 0.1-percent accuracy for any period within the total time. Total accuracy of better than 1 percent is achieved by the lash-free gear train, using Delrin gears, and regulation. (4 pp) Technology Instr. Corp., Acton, Mass.

NEW-Fluke Precision Potentiometers Provide 10 TURN RESOLUTION...



—Save: Time-Space-Effort-Cost

The **FLUKE** Model 20A Vernier Potentiometer provides resolution equivalent to that of 10 turn helical potentiometers with only 550° of shaft rotation. At the same time, the 20A requires only a fraction of the space occupied by helical potentiometers, and, in fact, occupies less space than many single turn, low resolution potentiometers.

This high resolution, small size, and ease of operation, is achieved by a unique **FLUKE** patented design. A schematic of the Model 20A is shown below. Basically, the Model 20A consists of a main resistance element and a concentric smaller vernier. The vernier element is connected to the main element through two contacts spaced 30° apart. This spreads any 30° segment of the main winding over the 270° of vernier rotation. The vernier slider is rotated by the potentiometer shaft. As the shaft is turned and the vernier slider completes its rotation, a mechanical stop causes the vernier frame to turn, moving the spaced vernier contacts along the main element. This method provides a coarse adjustment at either end of the vernier adjustment.

This unique design results in a versatile, high performance potentiometer. For example, thin card-type windings reduce residual reactance and allow operation at much higher frequencies than other potentiometers with similar DC specifications. The one and one-half turn control of the entire adjustment range allows substantial time savings in frequently adjusted or multiple potentiometer installations such as analog computers and data logging systems. Equipped with a screwdriver slotted shaft, the Model 20A also makes an ideal high resolution trimmer.

The Model 20A is available from stock in resistance values ranging from 100 ohms to 25 K ohms, and can be provided with a calibrated readout dial and lock-type knob.

If greater resistance values are required, write for information on the **FLUKE** Models 21A, 22A, and 30A. The Model 21A and 22A have increased power ratings and are available in resistance values to 100 K. The Model 30A features resolution of 20 times that of the 20A series, resistance values from 1 K to 100 K, and a power rating of 5 watts.

MODEL 20A PARTIAL SPECIFICATIONS

Standard Tolerance: ±5%, available to ±1% on special order Linearity ±0.5%

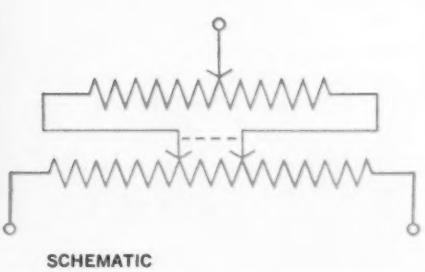
Resolution: 1000 ohms, 1 part in 5600. Increased resolution for higher values.

Power Rating: 2 watts at 20° C, derated to 0 at 100° C.

Price: As shown, $8.50.

NEW FLUKE MODEL 20A
Vernier Potentiometer

JOHN FLUKE MFG. CO. INC.
P. O. Box 7428 Seattle 33, Washington



MANUFACTURERS OF ELECTRONIC TEST AND MEASURING INSTRUMENTS FOR LABORATORY—PRODUCTION LINE

CIRCLE NO. 66 ON INQUIRY CARD

For Your 3-Ring Binder
NEW DATA SHEETS

Most of these data sheets contain complete specs, mounting configurations and other important details associated with the application of the products described. For your free copy of the data sheets listed on this page, enter the appropriate number of the item on the Inquiry Card.

Industrial Power Transistor 937

With a maximum dissipation of 30 watts at a base-mounting temperature of 25°C, medium power industrial transistor weighs less than 5 grams and requires ⅓ square inch of chassis space. The hermetically sealed germanium units are especially suited for use in servo motor controls, power amplifiers, converters, regulated power supplies and low-speed power switches. C.B.S. Electronics, Danvers, Mass.

Oscilloscope Accessory 903

Wherever frequency is changed often or continuously, tracking sweep control used with a CRO automatically locks sweep time to signal period for continuous monitoring of wave shape. CRO must always present an intelligible display at any frequency from 5 cps to 20 kc. Data sheet describes unit and lists applications. Chadwick-Helmuth Co., Monrovia, Calif.

Solenoid Valves 925

As an aid to selecting the proper solenoid valve, — size, pressure, temperature, coil type, special features and assemblies are presented in a condensed chart. CV flow factors used for quick and accurate sizing of valves are also tabulated. J. D. Gould Co., Indianapolis, Ind.

DC Voltage Comparator 900

As a building block in high speed, high sensitivity measurement and check-out systems, or for a precise go-no-go response, a precision comparator combines a faster response time and lower detectable difference than is presently available, according to its manufacturer. With this instrument, for example, one can design automatic testing systems with clock rates as high as 100 cps without sacrificing accuracy. Blocking lever is greater than 500x full-scale reference value. B-line Electronics, Inc., Cochituate, Mass.

Beryllium Copper Alloys 933

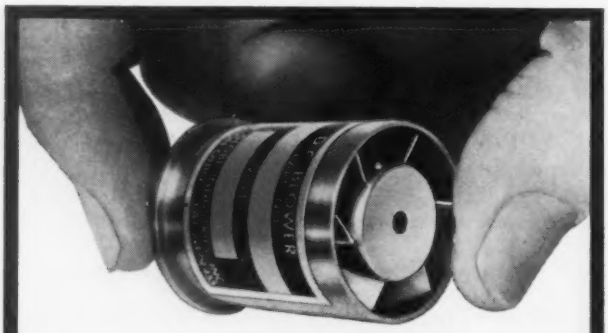
In addition to tensile strengths of up to 215,000 psi, beryllium copper alloys also have such desirable properties of copper as excellent formability, good thermal and electrical conductivity. Complete technical information on two high-strength and two high-conductivity beryllium copper strip products is contained in 4 data sheets. Methods of heat treating, forming, poining and plating of beryllium copper are covered. Brush Beryllium Co., Cleveland, Ohio.

FHP AC Motors 901

Specification sheet details design features of a new type split capacitor, fractional horsepower ac motor. Available in ratings from 1/15 hp to 1/2 hp, the motors are engineered for quiet, cool operation under severe conditions. Specs shown are for 115v, 60 cycle operation, although the motors can also be wound for 208 or 230-volt operation at 50 to 60 cycles. Leece-Neville Co., Gainesville, Ga.

Precision Potentiometer 936

For fast and easy modification, a precision potentiometer can be tapped and phased in the field. Unit is of modular design with each individual cup self-contained. Precision machined housing provides great flexibility in stacking; up to 15 units can be stacked without loss of accuracy due to de-centering. Mounting plate, shaft assembly and ganging rings, can be ordered separately. Instruments for Industry, Inc., Hicksville, N. Y.



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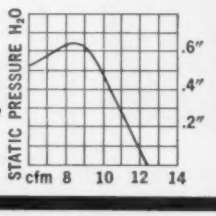
VANEAXIAL BLOWER

Only 1⅛" in diameter by a maximum 1¾" long, this smallest d.c. blower moves 10 cfm of air against 0.4" H_2O back pressure! Use this rugged sub-miniature blower for spot cooling of critical components where space is cramped and weight is important.

VAX-1-DC blower operates on 28 v.d.c. or less, using a maximum of 200 milliamps. Weight is 1.4 ounces. Mounts with standard servo ring clamps. (Globe makes larger blowers also.) Request Bulletin VAX-1 from Globe Industries, Inc., 1784 Stanley Avenue, Dayton 4, Ohio.



GLOBE INDUSTRIES, INC.

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- Storage
- Seasoning
- Testing

Seven Revco cabinets, both chest and upright styles, are available. Capacities range from 1.5 to 6 cu. ft. in chests and to 22 cu. ft. in uprights. Units provide temperatures to —140° F. controllable within ±1°. Optional accessories are offered. Immediate delivery on all units.

For your FREE copy of the helpful folder, "Selecting a low temperature cabinet," write Revco, Dept. EMD-101

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Extended dc output voltage range of ±111.11 volts, selectable in 10 millivolts steps, is the key performance characteristic of a new precision voltage source. Accuracy of 0.025% is obtained at 25%C ambient with a voltage coefficient of 0.002%/°C. Electronic Development Corp., Boston, Mass.

Distance Indicator 906

Bearing-distance-heading indicator displays simultaneous bearings to two reference points and distance to one of the points plus magnetic heading of an aircraft. Complete technical deals are given. John Oster Mfg. Co., Racine, Wis.

Micro-Midget Chopper 908

Specification sheet describes chopper and illustrates the minimum noise levels encountered in its use. Typical noise measuring circuit is shown and noise in microvolts is plotted as a function of load impedance. Airpax Electronics, Inc., Cambridge, Md.

Size 5 Servomotor 914

Designed for applications demanding minimum size and weight, a size 5 servomotor provides high torque with low rotor inertia for precise and rapid response to minimum control signals. Data given includes a torque-speed curve. Helipot Div., Beckman Instruments, Inc., Fullerton, Calif.

3/8" Square Trimmer Pot 940

Catalog sheet describes ⅜" square trimming potentiometer with a resistance value up to 50K ohms. Microminiature trimmer weighs only ¾ gram and has a power rating of one watt at 50°C, derating to zero at 175°C. Available in continuous or clutch stop models, the trimmer features an integrated high temperature plastic case, wire-wound resistance element, vibration-proof wiper, molded "O" ring, moisture-resistance seal and Teflon insulated lead wires or terminal pins "locked in." Techno-Components Corp., Northridge, Calif.

Permanent Magnet DC Motor 941

Meeting environmental requirements of MIL-M-8609 (ASG), a 1" diameter permanent magnet motor contains precision ball bearings, constant pressure springs to insure long brush life and explosion-proof housings. Typical applications include program switches, tuning mechanisms, timing devices, cooling fans and blowers and electromechanical actuators. Barber-Colman Co., Motors and Components Div., Rockford, Ill.

Sealed Precision Bearings 942

Effectively blocking out dirt and retaining bearing lubricant while operating at high speed in moderate to high temperatures, precision sealed bearings are particularly suited to applications requiring high lineal speeds. Design characteristics, performance ratings and dimensions are contained in a handy table. Barden Corp., Danbury, Conn.

Electrostatic Charge Amplifier 924

Compact line-powered instrument precisely converts electrostatic charge signals from accelerometers to voltage signals compatible with input requirements of oscilloscopes, recorders and telemetering equipment. Linearity and gain stability is better than 0.5%. Characteristics and ranges, plus alternate single, multiple, and multi-range models are covered in data sheet. Kistler Instrument Corp., No. Tonawanda, N. Y.

Micro-Miniature Resistors 913

Microminiature resistors, designed specifically for printed circuit applications, incorporate a new method of terminating the resistance wire. Using a pure silver base, a casting is made around the termination that bonds to both the wire and the terminal making one solid mass. Its strength exceeds twice that of a weld; it has a low contact resistance, and will not melt or flow when dipped into a solder pot. Reon Resistor Corp., Yonkers, N.Y.

Transistor Servo Amplifier 923

Servo amplifier for both 60 and 400 cps motors puts out 10 watts of instantaneous power. Used in ambients up to 71°C, the amplifier was designed for high performance industrial and military application, but is priced in the neighborhood of comparable vacuum tube units. Mechanical assembly of 3 functional wafers, connected by straight-feed thru connectors, provides simplicity and maximum reliability. Diehl Mfg. Co., Somerville, N. J.

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After Delivery Economies

Your end-costs are lower because:

- Bodine Motors perform consistently, never require field servicing . . . (well, almost never!)
- Bodine Motors are easy to fit-in . . easy to adjust.
- You seldom encounter inspection or test rejects.
- Bodine Motors help your product earn repeat sales.

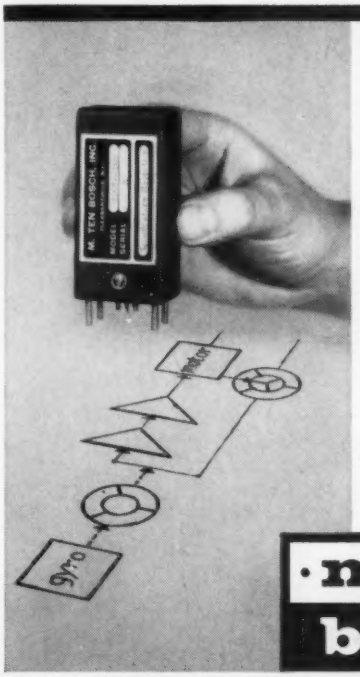
Ask for Bulletin S-2

BODINE fractional/horsepower MOTORS

Bodine Electric Company
2530 West Bradley Place, Chicago 18, Illinois

CIRCLE NO. 69 ON INQUIRY CARD

50-1 QUADRATURE REJECTION with a ***PLUG-IN*** TRANSISTOR AMPLIFIER



INPUT IMPEDANCE	500,000 ohms (A wide range of input values may be made available to suit source impedance requirements.)
LOAD IMPEDANCE	500 ohms
POWER GAIN	30 Db.
VOLTAGE GAIN	Unity
PHASE SHIFT	Zero
CARRIER FREQUENCY	380 to 420 c.p.s.
OUTPUT	450 millivolts minimum saturated signal at 500 ohm output impedance
INPUT-POWER REQUIREMENTS	28 V.D.C. at 12 ma.; 115 V. 400 c.p.s., 1 ma.

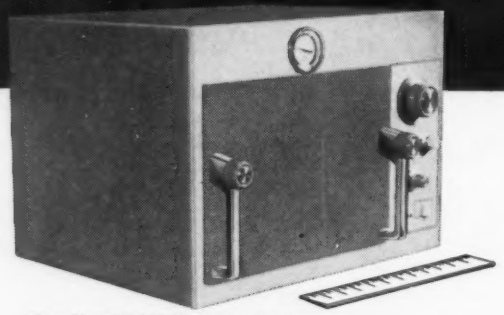
·m.ten bosch inc

For detailed QUADRATURE REJECTION AMPLIFIER SPECS, MODEL 1805-0500
Write to Dept. QR-1, M. Ten Bosch Inc., Pleasantville, New York

CIRCLE NO. 70 ON INQUIRY CARD

NEW! WYLE Miniature Temperature Chamber

For Small Parts and Black Boxes



Wyle Model C-106 Miniature Chamber

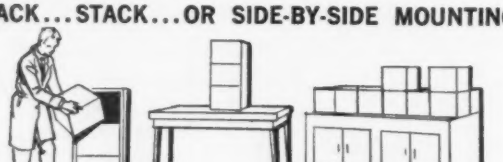
Offering You...

CLOSER TEMPERATURE CONTROL • COOLER OUTSIDE SKIN • BETTER OPERATING ECONOMY • GREATER FLEXIBILITY • FASTER HEATING & COOLING RATES

Revolutionary NEW "Sensor" The new Wyle liquid CO_2-cooled Model C-106 Miniature Temperature Chamber is the first to use a revolutionary new type electronic resistance bulb controller that "anticipates" temperature changes and thus effects minimum variation over the full range.

Extra thick layers of new, improved insulation retard flow of heat to outside skin . . . skin stays cooler. Interchangeable plug-in doors, with various provisions for specimen mounting, instrumentation, specimen operation, and observation, assure minimum downtime. All features lead to greater economy of operation.

RACK...STACK...OR SIDE-BY-SIDE MOUNTING



Fits standard 19" racks . . . Flush top & bottom . . . Flush sides

640 Cu. In. Capacity • −100°F to +500°F Range • 8" x 8" x 10" Test Volume Dimensions • Weight . . . Approx. 55 Lbs. • Heating & Cooling Rates . . . Up to 100°F per Minute

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The air pressure is the sealing force; the higher the pressure, the tighter the seal.

DIRECT SOLENOID 4-way, 3-way, shut-off and diverter valves

Standard **AC**

Explosion-proof **AC**

Standard **DC**

Explosion-proof **DC**

SOLENOID-PILOT 4-way and 3-way valves

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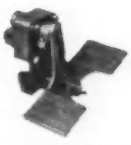
"MK" type manual override

MANUAL and FOOT OPERATED valves

Manual 4-way

Manual shut-off



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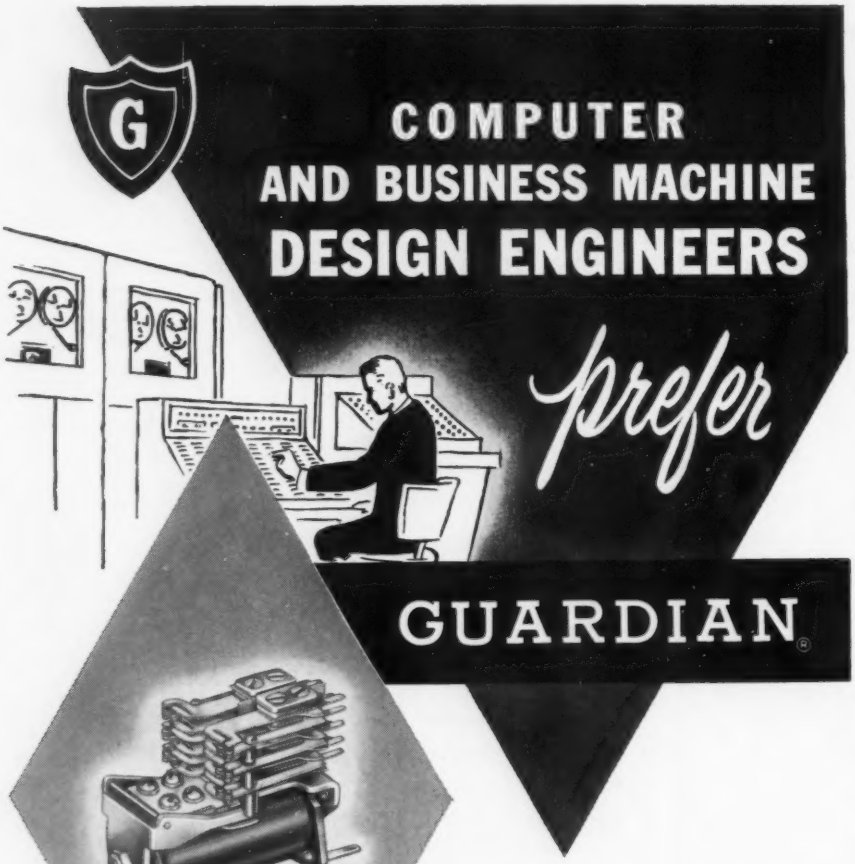

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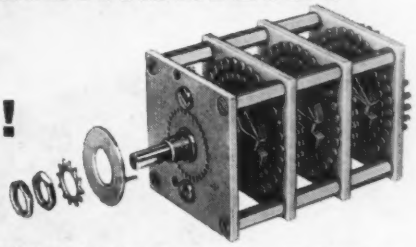

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A SUBSIDIARY OF GENERAL MILLS

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28.5 LB. AUTOMATIC DEAD RECKONING NAVIGATIONAL SYSTEMS

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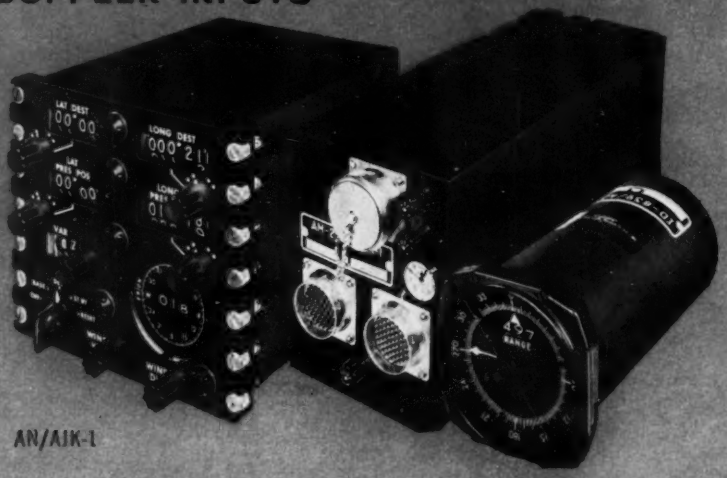

AN/AJK-1

These Sub-Miniature Systems provide:

• Continuous Latitude Longitude Present Position • Course and Remaining Distance to Destination • Course and Remaining Distance to Base or Alternate Destination • Automatic Display of Wind Velocity and Direction • Steering Information • True Ground Track

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OFFER HIGHEST ACCURACY. Why settle for more than 1% error in Present Position? Clifton units have been testing out better than 1%. Wind direction and force information from the Doppler has proved extremely accurate.

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CLIFTON HEIGHTS, PA.

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cppc SYSTEMS DIVISION